FISCAL YEAR 1990 DEPARTMENT OF ENERGY AUTHORIZATION

(Fossil Energy)

HEARING

BEFORE THE

SUBCOMMITTEE ON
ENERGY RESEARCH AND DEVELOPMENT

OF THE

COMMITTEE ON
SCIENCE, SPACE, AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

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* Ranking Republican Member.

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1990 DEPARTMENT OF ENERGY AUTHORIZATION

WEDNESDAY, FEBRUARY 22, 1989

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT,
Washington, DC.

The Subcommittee met at 9 a.m., in room 2325, Rayburn House Office Building, Hon. Marilyn Lloyd (chairman of the Subcommittee) presiding.

Present: Representatives Lloyd, Morrison, Smith, Traficant, Schiff, and Walgren.

OPENING STATEMENT OF HON. MARILYN LLOYD, CHAIRMAN, SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

Mrs. LLOYD. The Subcommittee will come to order. Good morning, ladies and gentlemen. Today, we continue our annual Authorization hearings on the Department of Energy's FY-1990 budget submission for Fossil Research and Development and the Clean Coal Technology Demonstration Program.

At the outset, I want to applaud the Administration for their continuing, serious commitment to the Clean Coal Program.

Our Subcommittee has been closely following the program since its inception and will continue our oversight in earnest this year.

The progress made to date in successfully negotiating projects from Round One and the large number of responses to the Round Two solicitation also shows the public interest in participating in this important program.

I believe that a successful conclusion to the Clean Coal Program will benefit our energy future, particularly as we deal with the issues of acid rain and global warming.

By providing time and the framework of the Clean Coal demonstration program, we bring experience gained from our research and development efforts to fruition, we're maximizing the benefits of previous research activities and scarce research dollars.

As pleased as I am with the Administration's support for Clean Coal, I must express dismay with the budget submission with regard to the Fossil Research and Development programs. The 57 percent reduction from FY-1989 appropriated levels calls into question a United States commitment to civilian energy research and development.

Daily, we hear of the threats of our foreign competition and the lack of support for our United States technology development.

Clearly, we can no longer meet our competition dollar for dollar without great sacrifices in many of our important programs.

In lieu of this ability, I believe that we must maximize each federal dollar. To do so, we must keep our base research programs intact and attempt to bring some of the nearer-term technologies out of the laboratories and into use.

Let's not throw away our investment dollars by prematurely halting necessary programs. During our hearings, we will carefully scrutinize the programs in an attempt to make the difficult funding judgments called for in the authorization process.

We will look forward to hearing from our witnesses and, again, their insights as we deliberate the energy issues.

I do want to recognize my colleague, Sid Morrison, who is the ranking Republican member, for his opening statement.

OPENING STATEMENT OF HON. SID MORRISON, RANKING REPUBLICAN, SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

Mr. **Morrison**. Thank you, Madam Chairman. And I do have a formal statement I will submit for the record.

I look forward today with catching up with the progress in Clean Coal and I'm pleased, as you are, with the budget efforts in this area. But, very concerned about the balance that we see. I think we should have a very serious concern about a number of energy areas, and there are significant cuts in some areas.

And I think the balance that we need to provide for in the 1990 budget will require some effort on the part of this Subcommittee.

And, Madam Chairman, with your permission, I would like to yield to my good friend and colleague, Lamar Smith, from Texas, who is my expert as far as this subject area is concerned.

[The prepared opening statement of Mr. Morrison follows:]

OPENING STATEMENT
HON. SID MORRISON
FY 1990 DOE AUTHORIZATION - FOSSIL ENERGY
FEBRUARY 22, 1989

GOOD MORNING. TODAY WE ARE REVIEWING THE ADMINISTRATION'S BUDGET REQUEST FOR FOSSIL ENERGY. I THINK R&D EFFORTS TO INCREASE THE USE OF CLEAN COAL, AS WELL AS TO INCREASE THE AVAILABILITY OF OIL AND NATURAL GAS RESOURCES ARE VERY IMPORTANT, BECAUSE OUR NATION DEPENDS ON FOSSIL ENERGY FOR 90% OF THE ENERGY REQUIREMENTS.

BECAUSE COAL IS THE LARGEST DOMESTIC FOSSIL ENERGY RESOURCE AND IS COMPARATIVELY UNDER-UTILIZED, I CAN SEE THAT OUR FOSSIL ENERGY R&D PROGRAM INVESTS HEAVILY ON COAL TECHNOLOGY DEVELOPMENT. I AM PLEASED WITH THE PROGRESS MADE IN THE CLEAN COAL TECHNOLOGY PROGRAM, AND I BELIEVE A STRONG INDUSTRY INVOLVEMENT IS A SUCCESS FACTOR. I THINK PRESIDENT BUSH'S PROPOSAL TO NOT STRETCH OUT THE SCHEDULE OF THIS PROGRAM IS A CONSTRUCTIVE MOVE TOWARD COMMERCIALIZING SOME OF THE OPTIONS AS EARLY AS THE MID 1990'S.

MY MAJOR CONCERN ABOUT FOSSIL ENERGY R&D REMAINS TO BE PROGRAM BALANCE. THE PRESIDENT'S REQUEST FOR 1990 INCREASED THE FUNDING FOR CLEAN COAL TECHNOLOGY AND WASTE MANAGEMENT, BUT REDUCED THE FUNDING FOR ALL OTHER PROGRAMS TO MUCH BELOW THE CURRENT YEAR APPROPRIATED LEVEL. I WOULD NOT LIKE TO BELIEVE THAT IN ORDER TO KEEP OUR CLEAN COAL TECHNOLOGY PROGRAM ON TRACK, WE MUST ROB PETER TO PAY PAUL, AND STRETCH OUT THE SCHEDULE OF OTHER MAJOR PROGRAMS. IF WE ARE SERIOUS

ABOUT ENHANCING THE USE OF OUR NATURAL RESOURCES AND MITIGATING THE GREENHOUSE EFFECT AND ACID RAIN, WE MUST CONTINUE TO PROVIDE ADEQUATE FUNDING TO MAINTAIN VIABILITY OF ADVANCED R&D PROGRAMS IN OIL, GAS, AND COAL TECHNOLOGIES INCLUDING FUEL CELLS AND MHD (MAGNETO-HYDRO-DYNAMICS).

MADAM CHAIRMAN, I LOOK FORWARD TO HEARING FROM OUR WITNESSES TODAY, AND WORKING WITH YOU TO RESOLVE FUNDING AND OTHER ISSUES OF THESE PROGRAMS.

Mrs. LLOYD. And we do look forward to hearing from Mr. Smith at this time, certainly a very valuable member of this Committee, has really made a tremendous contribution to the Subcommittee, especially in the area of fossil energy.

Mr. Smith.

OPENING STATEMENT OF THE HONORABLE LAMAR SMITH, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF TEXAS

Mr. SMITH. Thank you, Madam Chairman. I, like you, look forward to what the witnesses have to say today, particularly on the subject of oil and gas, as has been pointed out, which is of special interest not only to me but to a great many individuals who represent States in the Southwest.

And I might add that I think we're learning this year and I think many individuals are becoming more and more aware of the fact that fossil energy, particularly natural gas, is going to be of increasing importance to all individuals wherever they live in the country.

Thank you, Madam Chairman.

Mrs. LLOYD. Thank you very much, Mr. Smith. And without objection, recording and filming of the hearings of today's proceedings will be allowed. So ordered.

Our first witness today is the Honorable J. Allen Wampler, who is Assistant Secretary for Fossil Energy at the Department of Energy. He's been before our Subcommittee many times and he's always given us valuable insight into the programs.

Allen has been a champion of fossil and clean coal programs and I believe that he deserves much of the credit for the success of the programs so far.

We appreciate you, Allen, and would you like to identify your associate?

Mr. WAMPLER. Yes, Madam Chairman. Jerry Walsh, who is my principal deputy; also other members of the staff that are behind me, if necessary.

Mrs. LLOYD. You've got a good back-up crew today.

Mr. WAMPLER. Certainly do.

Mrs. LLOYD. Good. Please proceed.

STATEMENT OF J. ALLEN WAMPLER, ASSISTANT SECRETARY FOR FOSSIL ENERGY, U.S. DEPARTMENT OF ENERGY

Mr. WAMPLER. Thank you, Madam Chairman and Members of the Subcommittee. I'm pleased to present the Department's Fiscal Year 1990 budget for Fossil Energy Research and Development and the nation's whole technology program.

The testimony that we've submitted today is, admittedly, very lengthy and I appreciate the Committee's consideration in placing the full text into the record.

The major elements of our 1990 budget proposal are discussed in the first 16 pages of the statement, and with the Subcommittee's permission, I would just briefly like to highlight the key things.

Mrs. LLOYD. Without objection.

Mr. WAMPLER. Our budget request reflects President Bush's decision to reinstate the five-year funding schedule for the whole technology program. The President is committed to this program; he views it as the key element of an aggressive attempt by his Administration to resolve once and for all the issue of acid rain.

Obviously, we were pleased by the inclusion of this program in the President's February budget address to Congress.

Clearly, Madam Chairman, we have 29 Clean Coal projects either underway or in negotiation. The projects were selected in Rounds Number One and Two of the program. Together, they have a value approaching $2.3 billion. Perhaps more importantly, they offer private cost-sharing amounting to $6 for every $4 in federal funds.

We will begin Round Three of the program in May. Round Three will offer approximately $537 million in project financing out of the total of $575 million previously appropriated for fiscal 1990.

The President's decision to adhere to the previous Clean Coal schedule, which has been agreed to with Canada, should send two strong signals.

First, the President wants the Clean Coal Program to proceed at a pace that will make it an integral part of a comprehensive solution to acid rain.

And, second, the private companies should be competent that they can apply their own resources both in the R&D and demonstration stage with assurance that federal Clean Coal funding will be competitively available to complete an emerging technology's transition into the marketplace.

This latter point is particularly important, Madam Chairman. The President's budget message not only asks that the FY-90 appropriation remain in tact, but that Congress provide the remaining $1.2 billion for Rounds Four and five.

Advanced appropriations will inject a greater measure of certainty into the program and knowing these funds will be available will permit industry to devote a greater amount of their own resources to the concepts now in the R&D process.

The Clean Coal Program is certainly the most visible of our fossil energy related efforts, but it shouldn't over-shadow the importance of a sound core level of research and development.

At first glance, Madam Chairman, the Fossil R&D budget appears to be a substantial reduction from the 1989 appropriated level. But, fully one-third of the difference can be attributed to only four factors.

First, that the Administration is not proposing to fund the MHD program. As in past years, the issue is affordability. For many years now, the government has borne by far the largest financial share of this program, well above the 90 percent level, and we simply cannot allocate this large amount of funding without seeing greater leveraging of our dollars through private or other types of cost-sharing.

Second, no funds are requested for phosphoric acid fuel sales. Development will continue using prior year funds and the private sector should be willing to take the lead in the final commercialization stage of this technology.

Third, our work at Wilsonville and LaPorte liquefaction facilities has reached very successful conclusion. When market conditions are right, industry will be well-positioned to make the concepts tested at these units into commercial use.

And fourth, we've completed our funding commitments for two Congressionally-added construction projects at West Virginia University and the University of Oklahoma.

The other large construction items in last year's budget—the administration building at Morgantown and Pittsburgh Energy Technology Centers are simply not affordable in times of budget constraint.

Within the $165 million R&D budget request, however, we retain several key elements.

We have a significant commitment to new technologies that can reduce acid rain-related pollutants. Roughly 70 percent of our coal R&D program is oriented to these types of projects.

Many of the projects that would be continued in the FY-1990 could ultimately offer options that reduce the release of CO_2, compared to conventional coal technology.

The issue of CO_2 and global climate change is an important issue that deserves sound scientific investigation. There are still many unknowns.

However, while we await the outcome of ongoing research, it's important that we pursue technological options. Highly efficient combustion technologies, new concepts in pollution control, and other innovative energy technologies can provide significant energy benefits while at the same time reducing CO_2 and other suspect emissions. And many of these are included in our program.

We are cognizant of the liquids problem facing this country in the form of rising oil imports. So just over a third of our R&D budget applies to technologies that can provide alternate sources of liquid fuels. From a percentage standpoint, it's important to point out that this is greater than last year's budget request.

We proposed several new initiatives to boost prospects for Western coal. Our goal is to expand coal use in the West—perhaps, for example, as a feedstock for the Western railroad industry, or as an export commodity to the Pacific Rim.

We believe new technology offers some excellent opportunities to make full use of all our coal resources, both in the East and the West.

We continue to place a great deal of emphasis on oil and gas research with a clear focus on transferring existing and emerging technologies to industry.

Our geoscience program, in particular, has been strengthened largely, I might point out, as a result of this Committee's leadership and will continue to provide both financial and staff resources to ensure that the Nation's geoscience knowledge base is enhanced.

We have begun significant new efforts in both heavy and light oil recovery. Our program now includes projects that can be of near-term benefit particularly to the marginal oil producer, including the stripper well operator that is hurt each time there is a radical swing in oil prices. We have new projects underway in microbial enhanced recovery, as well as in the more traditional EOR processes.

In the gas area, we are assessing the results of major field tests in tight sands and Devonian shale, and we've begun an intensive effort to examine the potential for "secondary gas recovery." Our program is well-coordinated with and complementary to the program of the Gas Research Institute.

In the area of technology transfer, we have a new initiative ongoing with the Interstate Oil Compact Commission, with the newly-formed partnership involving Los Alamos and Sandia National Labs; to transfer the spin-off of technologies from weapons development that are applicable to the hydrocarbon geoscience area.

In conclusion, Madam Chairman, the budget we have presented is a solid budget. Every program it contains offers the Nation potentially significant energy and environmental benefits.

The programs it doesn't contain are not necessarily bad programs. They were simply weighed against areas where government could best apply its funding.

The projects and programs that emerged from this balancing are the ones that we believe need federal assistance the most, or which, in turn, will return the most benefits for the investment of tax dollars.

That completes my opening statement and I'll be pleased to attempt to answer any questions you have.

[The prepared statement of Mr. Wampler follows:]

The FY 1990 Fossil Energy Budget Request

Statement by J. Allen Wampler
Assistant Secretary for Fossil Energy
U.S. Department of Energy
to the
Subcommittee on Energy Research and Development
Committee on Science, Space and Technology
House of Representatives
February 22, 1989

The Department of Energy's FY 1990 fossil energy budget request strikes a balance between the need for fiscal stringency and the need to sustain the momentum of programs that are producing cleaner, more efficient processes for the fuels that supply nearly 90 percent of our country's energy requirements.

Coal, oil and natural gas are the mainstays of our energy economy. Together, they supply directly two-thirds of the energy used by the industrial sector, one-third of the energy used by residential and commercial establishments, and virtually all of our transportation fuel requirements. As fuels for electric power generation, they account for approximately 70 percent of the electricity produced in this country which, in turn, is used by the other end-use sectors to produce much of the nation's goods and services.

Fossil fuels have contributed greatly to our standard of living. If we are to maintain and improve that standard in the foreseeable future, we must continue to look to these fuels as a fundamental component of our domestic energy industry. Our objective, therefore, must be to develop technologies that can ensure that fossil fuels can continue to be used without compromising our environmental or economic goals.

Recently, the potential conflicts between energy and environmental objectives have received heightened attention in debates over the consequences of acid rain and the release of so-called "greenhouse gases" from fossil fuel combustion. Scientific understanding of these problems is still far from complete, and the costs of overreaction could impose a staggering burden on the nation's future economic growth and prosperity.

In addition, new concerns have been raised about the future reliability of electric power capacity with reserve margins in some areas of the country having diminished at greater-than-expected rates. The nation's long-term competitiveness in international markets is also a matter of national concern, and how well we respond to our domestic environmental, economic and energy challenges will dictate, in large part, how fast — and to what extent — we are successful in restoring a more favorable balance of trade.

Consequently, if new technological solutions can be found that meet our environmental objectives, while at the same time being more cost effective and efficient than today's options, future policy decisions can be made in a manner that reflects both our social goals and our need to maintain a strong, energy secure nation.

The FY1990 Fossil Energy budget has been formulated with this objective in mind. The budget consists of two major components (with their FY 1990 funding requests).

- **The Clean Coal Technology Demonstration Program — $710.0 million**
- **The Fossil Energy Research and Development Program — $163.6 million.**

Clean Coal Technology Demonstration Program

The Clean Coal Technology Program is a government-industry, co-funded effort to demonstrate advanced concepts for using coal cleanly and more efficiently than today's technology. Begun by Congress in 1986 and expanded by President Reagan in 1987 (in response to recommendations from the U.S. and Canadian Special Envoys on Acid Rain), the program is expected to finance more than $5 billion of projects when completed in the 1990s, with at least half of the funding provided by the private sector.

(If the ratio of private to public cost-sharing experienced in the first two rounds of competition — approximately 60/40 — remains consistent for the entire program, the Clean Coal program would finance more than $6.25 billion of demonstration projects.)

In contrast to the more fundamental projects undertaken in the coal portion of the Fossil Energy Research and Development Program, the Clean Coal Technology Demonstration Program provides financial assistance for commercial scale or near-commercial scale ventures. By building and operating these first-of-a-kind plants, industry can obtain data on construction and operating costs, reliability, maintenance and other performance factors that are necessary to make commercial deployment decisions.

Program Status. To date, two rounds of competition have been completed, one in 1986, the other last year. The competitions have resulted in the selection of 29 projects with a total value estimated at more than $2.3 billion. Nine of the projects, totaling approximately $860 million, have completed negotiations and are underway. They are listed in the chart at the top of the next page.

Negotiated Clean Coal Technology Projects

Project	Industry	DOE	Total
Tidd PFBC Demonstration Project	$107,300,000	$60,200,000	$167,500,000
Advanced Cyclone Combustor Demonstration Project	$392,992	$392,992	$785,984
LIMB Demonstration Project	$11,807,914	$7,597,026	$19,404,940
Gas Reburning/Sorbent Injection Demonstration Project	$15,000,000	$14,998,253	$29,998,253
Underground Coal Gasification Demonstration Project	$58,323,092	$11,792,362	$70,115,454
The Appalachian IGCC Demonstration Project	$156,309,000	$87,528,000	$243,837,000
Prototype Coal/Oil Coprocessing Demonstration Project	$180,674,805	$45,000,000	$225,674,805
Colorado-Ute Circulating AFB Demonstration Project	$34,167,000	$19,920,000	$54,087,000
TRW Advanced Slagging Combustor Demonstration Project	$25,480,000	$23,520,000	$49,000,000
TOTAL	$589,454,803	$270,948,633	$859,403,436

The remaining 20 projects (4 selected in Round #1 and 16 selected in Round #2) are in negotiations with the Department.

FY 1989 Congressional Budget Action. In FY 1989 budget action, Congress spread the appropriations to complete Round #2 ($525 million) over three years, providing $190 million in FY 1989, $135 million in FY 1990 and $200 million in FY 1991. The Congress also approved the Department's request for $575 million for FY 1990 to support a third round of competition.

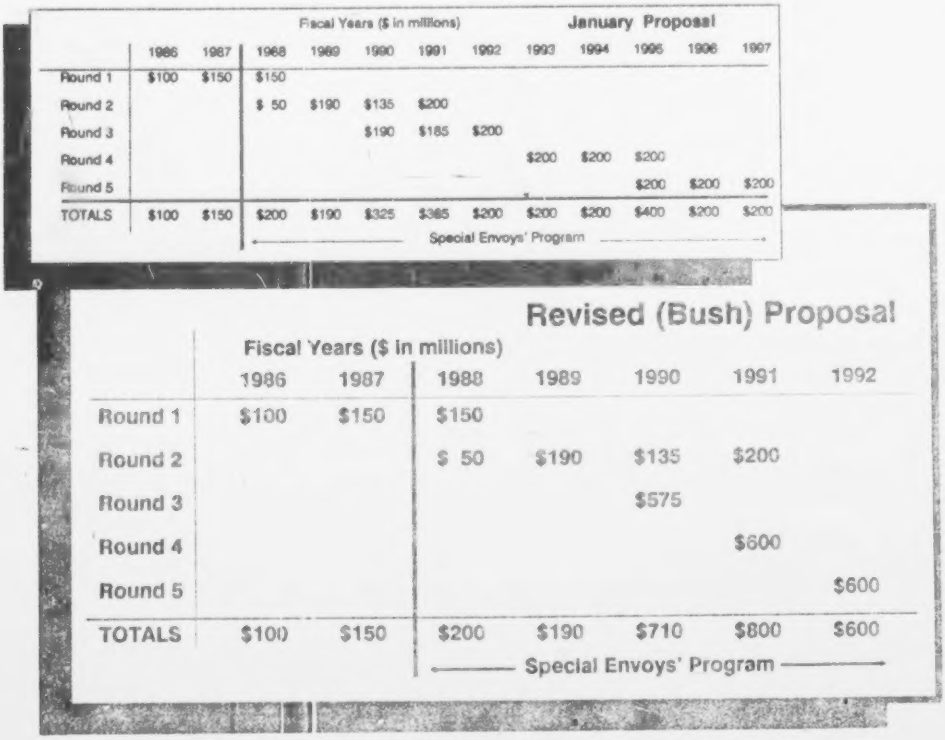
FY 1990 Administration Budget Request. In its initial FY 1990 budget request (January 1989), the Department proposed to extend the $575 million previously appropriated for the third round of competition over three years (FY 1990-92) and to defer completion of funding for the full $2.5 billion program until FY 1997 (rather than the original completion date of FY1992).

On February 9, 1989, President Bush reinstated the original 5-year appropriations timetable of the program. In his budget message to Congress, the President said:

We must make use of clean coal. My budget contains full funding, on schedule, for the clean coal technology agreement that we've made with Canada. We've made that agreement with Canada and we intend to honor that agreement.

President Bush's revised budget would adhere to the previous Congressional appropriation of $575 million in FY 1990 for a third round of competition (due to begin in May), plus $135 million previously earmarked for the second round of competition. The President is also requesting Congress to appropriate the remaining $1.2 billion to complete the $2.5 billion (federal share) recommended by the U.S.-Canadian Special Envoys on Acid Rain. This funding – $600 million in each of fiscal years 1991 and 1992 – would be used as the federal share of projects selected in the final two solicitations

The proposed funding schedule (along with the prior FY1990 proposal) is shown in the following chart:



January Proposal

Fiscal Years ($ in millions)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Round 1	$100	$150	$150									
Round 2			$ 50	$190	$135	$200						
Round 3					$190	$185	$200					
Round 4								$200	$200	$200		
Round 5										$200	$200	$200
TOTALS	$100	$150	$200	$190	$325	$385	$200	$200	$200	$400	$200	$200

Special Envoys' Program

Revised (Bush) Proposal

Fiscal Years ($ in millions)

	1986	1987	1988	1989	1990	1991	1992
Round 1	$100	$150	$150				
Round 2			$ 50	$190	$135	$200	
Round 3					$575		
Round 4						$600	
Round 5							$600
TOTALS	$100	$150	$200	$190	$710	$800	$600

Special Envoys' Program

The Importance of Full Appropriations. President Bush has emphasized that the Clean Coal Technology Program is an integral part of his commitment to cleaner air and protection of the environment. The President has also stated his commitment to ending the long debate on acid rain through a program to obtain significant reductions of acid rain precursor pollutants by a specific date.

If the Clean Coal Technology Program is to provide the U.S. with new, more cost-effective options to meet the President's environmental goals, it is important for Congress to approve advance appropriations for the $1.2 billion required to complete the program.

By appropriating in advance funds for the remaining rounds of competition, Congress can send a strong message to industry that the government's commitment to clean coal technology remains intact and that research projects now in the development stage should be continued so that they can be considered for future support. If industry has confidence that such cost-sharing will be available for the final pre-commercialization step, it will have a greater incentive to contribute its own funds to the development of new, more innovative concepts.

The result would be:

- more industry cost-sharing at earlier stages of development, thereby permitting greater leveraging of federal research funds, and
- the evolution of better, more effective technologies as candidates for joint demonstration funding and ultimately, for commercial replication and deployment.

Congress would continue to help shape the future course of the program through its oversight and annual appropriations process. The Department would continue to adhere to Congressional guidance, and the opportunity would continue to exist for modifying criteria and other guidelines for future rounds of competition to reflect lessons learned and, if necessary, to incorporate new considerations or priorities.

Fossil Energy Research and Development Program

In contrast to the Clean Coal Technology Demonstration Program, the Fossil Energy Research and Development Program is oriented toward the earlier stages of the development process — i.e., the basic and applied research stages through the early stages of process engineering. For the most part, the technologies pursued are longer-range and higher-risk, but if successfully developed, could offer potentially greater benefits in terms of economics, efficiencies and/or effectiveness. The program is comprised of coal, petroleum, natural gas and several policy and management functions. Also, in FY 1990, a new line item has been added for *environmental restoration*.

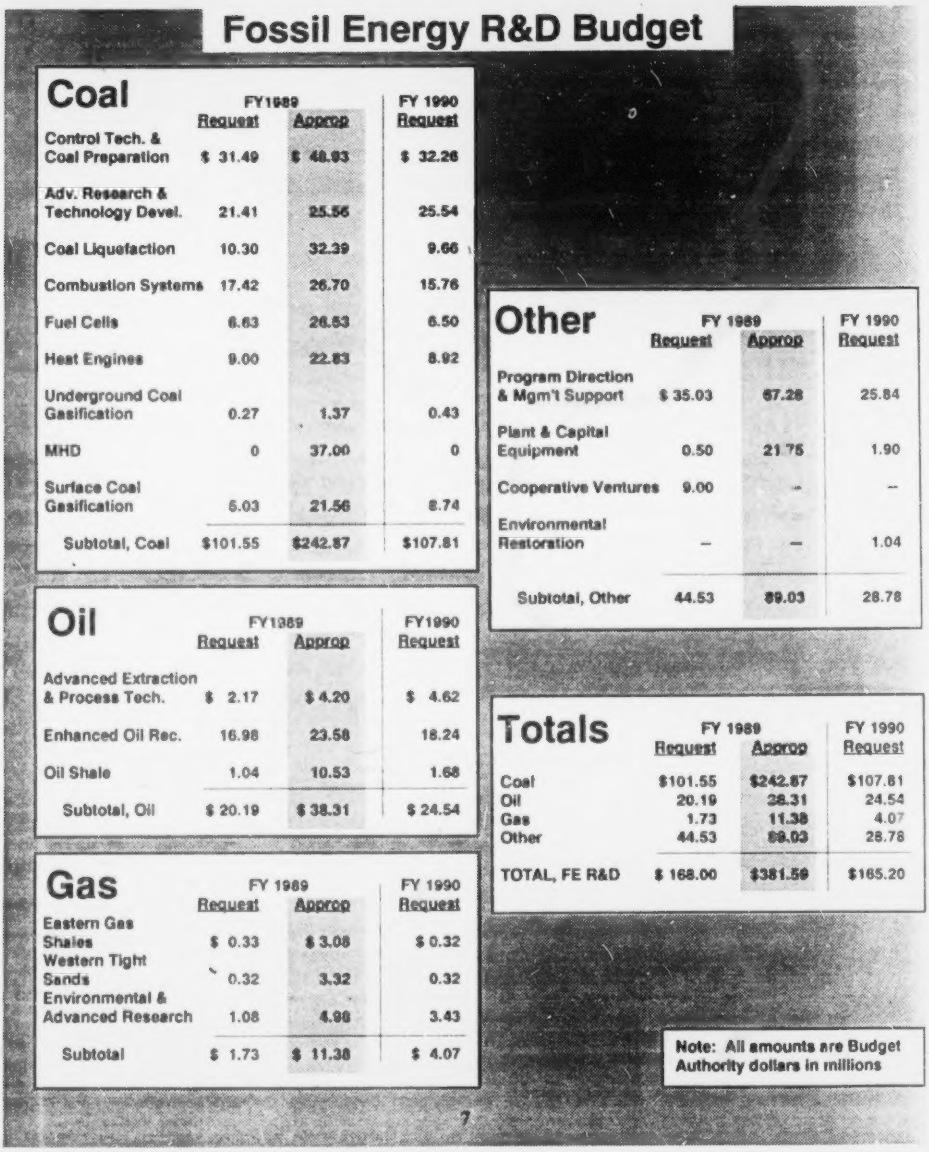
The FY 1990 budget request is consistent with the FY 1989 request.

The FY 1990 budget request, while well below the FY 1989 enacted level, is consistent with last year's request. The proposed funding reflects an appreciation of the need to limit federal spending and to concentrate available federal funds on high-risk, high-potential projects which industry cannot be expected to finance on its own.

The differences between the FY 1990 request and the funding levels appropriated by Congress for FY 1989 are governed primarily by the need for fiscal restraint. However, fully one-third of the difference between the FY 1989 appropriation and the FY 1990 request — or $73 million out of a difference of $217 million — can be attributed solely to four factors:

- The Administration is not proposing to continue the magnetohydrodynamics (MHD) program funded in FY 1989 at $37 million.
- The development of the phosphoric acid fuel cell concept has progressed to the point where any further federal involvement can be funded with previously appropriated funds; in FY 1989, phosphoric acid fuel cell funding amounted to $9.5 million.
- Work successfully concludes this year at the Wilsonville (AL) and LaPorte (TX) coal liquefaction test facilities. Significant advances have been achieved and a substantial data base now is in place. Industry is in the position to commercialize these technologies when market conditions are appropriate. Completion of work at these facilities will permit a reduction of $8.4 million from the FY 1989 appropriations.
- The Administration has completed its funding commitments for Congressionally added construction projects at West Virginia University and the University of Oklahoma. It cannot support continued funding for construction of an administrative office buildings at the Morgantown and Pittsburgh Energy Technology Centers in these times of budgetary constraint. These projects accounted for $18.25 million in the FY 1989 budget.

A comparison of the FY 1989 and FY 1990 budgets is shown in the following chart:



Fossil Energy R&D Budget

Coal

	FY1989 Request	FY1989 Approp	FY 1990 Request
Control Tech. & Coal Preparation	$ 31.49	$ 48.93	$ 32.26
Adv. Research & Technology Devel.	21.41	25.56	25.54
Coal Liquefaction	10.30	32.39	9.66
Combustion Systems	17.42	26.70	15.76
Fuel Cells	6.63	26.53	6.50
Heat Engines	9.00	22.83	8.92
Underground Coal Gasification	0.27	1.37	0.43
MHD	0	37.00	0
Surface Coal Gasification	5.03	21.56	8.74
Subtotal, Coal	$101.55	$242.87	$107.81

Oil

	FY1989 Request	FY1989 Approp	FY1990 Request
Advanced Extraction & Process Tech.	$ 2.17	$ 4.20	$ 4.62
Enhanced Oil Rec.	16.98	23.58	18.24
Oil Shale	1.04	10.53	1.68
Subtotal, Oil	$ 20.19	$ 38.31	$ 24.54

Gas

	FY 1989 Request	FY 1989 Approp	FY 1990 Request
Eastern Gas Shales	$ 0.33	$ 3.08	$ 0.32
Western Tight Sands	0.32	3.32	0.32
Environmental & Advanced Research	1.08	4.98	3.43
Subtotal	$ 1.73	$ 11.38	$ 4.07

Other

	FY 1989 Request	FY 1989 Approp	FY 1990 Request
Program Direction & Mgm't Support	$ 35.03	67.28	25.84
Plant & Capital Equipment	0.50	21.75	1.90
Cooperative Ventures	9.00	–	–
Environmental Restoration	–	–	1.04
Subtotal, Other	44.53	89.03	28.78

Totals

	FY 1989 Request	FY 1989 Approp	FY 1990 Request
Coal	$101.55	$242.87	$107.81
Oil	20.19	38.31	24.54
Gas	1.73	11.38	4.07
Other	44.53	89.03	28.78
TOTAL, FE R&D	$ 168.00	$381.59	$165.20

Note: All amounts are Budget Authority dollars in millions

- **The FY 1990 budget request continues high priority research in acid rain and CO_2 mitigation technologies, and in the production of alternative liquid fuels, as well as new initiatives in western coal research.**

Even given the reductions from the FY 1989 appropriations, the FY 1990 Fossil Energy budget request offers the nation a viable research and development program that incorporates both new initiatives and continued priority given to pressing national concerns. For example:

Acid Rain-Related Funding. There is a continued emphasis on technologies that can reduce the release of pollutants associated with acid rain. As the chart on the next page shows, **research and development** of technologies that can have a direct impact on reducing acid rain-causing pollutants accounts for $76.5 million, or roughly 70 percent of the proposed coal research and development program.

The United States has achieved an excellent record of environmental progress. Since passage of the Clean Air Act in 1970, U.S. industry has spent nearly $250 billion to control air emissions. As much as $70 billion of this has been spent by the nation's coal-burning utilities to reduce sulfur dioxide (SO_2) emissions alone. Because of this investment, the nation's air is cleaner today than at any time in the last decade. SO_2 emissions from all sources have dropped 28 percent from their peak in 1973, while at the same time, coal use has increased by nearly 80 percent. New pollution control technologies, many of which will have their origins in the federal R&D program, will lead to further reductions in acid rain-causing pollutants.

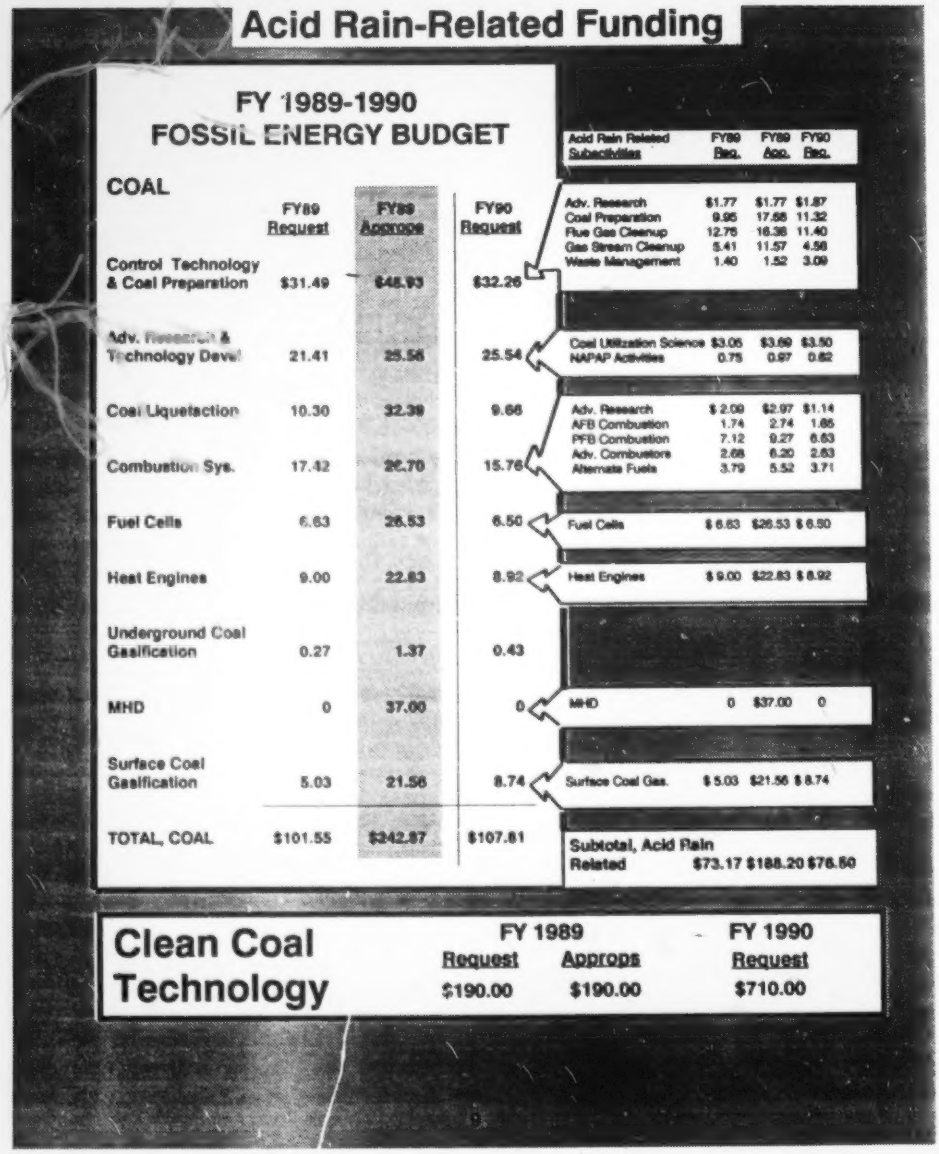
The Administration will ask Congress to establish an acid rain program that will obtain significant SO_2 and NO_x emission reductions by specified dates. Much of the basis for this program will come from:

1) an intensive, 10-year, multi-agency effort to understand better the scientific causes and effects of acid precipitation. This effort is termed the National Acid Precipitation Assessment Program;

2) a *parallel* effort to develop new technologies that can expand the menu of available options for continuing or, if necessary, accelerating the reduction of acid rain-causing pollutants, and

3) identification of incentives that can be provided or disincentives that can be removed to ensure early deployment of better emission control technologies.

Most of the acid rain-related funding in this budget request is oriented toward the second element of the Administration's acid rain response. As the chart on the next page shows, the funding levels represent a significant national commitment to more economical and effective pollution control methods for the 1990s and 21st Century.



Acid Rain-Related Funding

FY 1989-1990
FOSSIL ENERGY BUDGET

COAL

	FY89 Request	FY89 Approps	FY90 Request
Control Technology & Coal Preparation	$31.49	$48.93	$32.26
Adv. Research & Technology Devel	21.41	25.56	25.54
Coal Liquefaction	10.30	32.39	9.66
Combustion Sys.	17.42	26.70	15.76
Fuel Cells	6.63	26.53	6.50
Heat Engines	9.00	22.83	8.92
Underground Coal Gasification	0.27	1.37	0.43
MHD	0	37.00	0
Surface Coal Gasification	5.03	21.56	8.74
TOTAL, COAL	$101.55	$242.87	$107.81

Acid Rain Related Subactivities	FY89 Req.	FY89 App.	FY90 Req.
Adv. Research	$1.77	$1.77	$1.87
Coal Preparation	9.95	17.58	11.32
Flue Gas Cleanup	12.76	16.38	11.40
Gas Stream Cleanup	5.41	11.57	4.58
Waste Management	1.40	1.52	3.09
Coal Utilization Science	$3.05	$3.69	$3.50
NAPAP Activities	0.75	0.97	0.82
Adv. Research	$ 2.09	$2.97	$1.14
AFB Combustion	1.74	2.74	1.65
PFB Combustion	7.12	9.27	6.63
Adv. Combustors	2.68	6.20	2.63
Alternate Fuels	3.79	5.52	3.71
Fuel Cells	$ 6.63	$26.53	$ 6.50
Heat Engines	$ 9.00	$22.83	$ 8.92
MHD	0	$37.00	0
Surface Coal Gas.	$ 5.03	$21.56	$ 8.74
Subtotal, Acid Rain Related	$73.17	$188.20	$76.50

Clean Coal Technology	FY 1989 Request	FY 1989 Approps	FY 1990 Request
	$190.00	$190.00	$710.00

CO_2 Mitigation Technologies. Many of the technologies being developed in the Fossil Energy program can have a positive impact on the reduction of so-called "greenhouse gases" such as carbon dioxide (CO_2).

The question of whether the earth is warming because of the accumulation of so-called "greenhouse gases" is a matter of debate and conflicting scientific analysis. Moreover, there remain significant questions about the relative contributions of various human activities — for example, fossil fuel combustion versus global deforestation — and the relative effectiveness of policy actions taken by any single nation, even one as large as the U.S., to control or reduce such emissions. For example, U.S. coal combustion contributes to less than eight percent of the total worldwide release of CO_2, and in both the U.S. and western Europe, there has been little growth in CO_2 emissions since the 1970s.

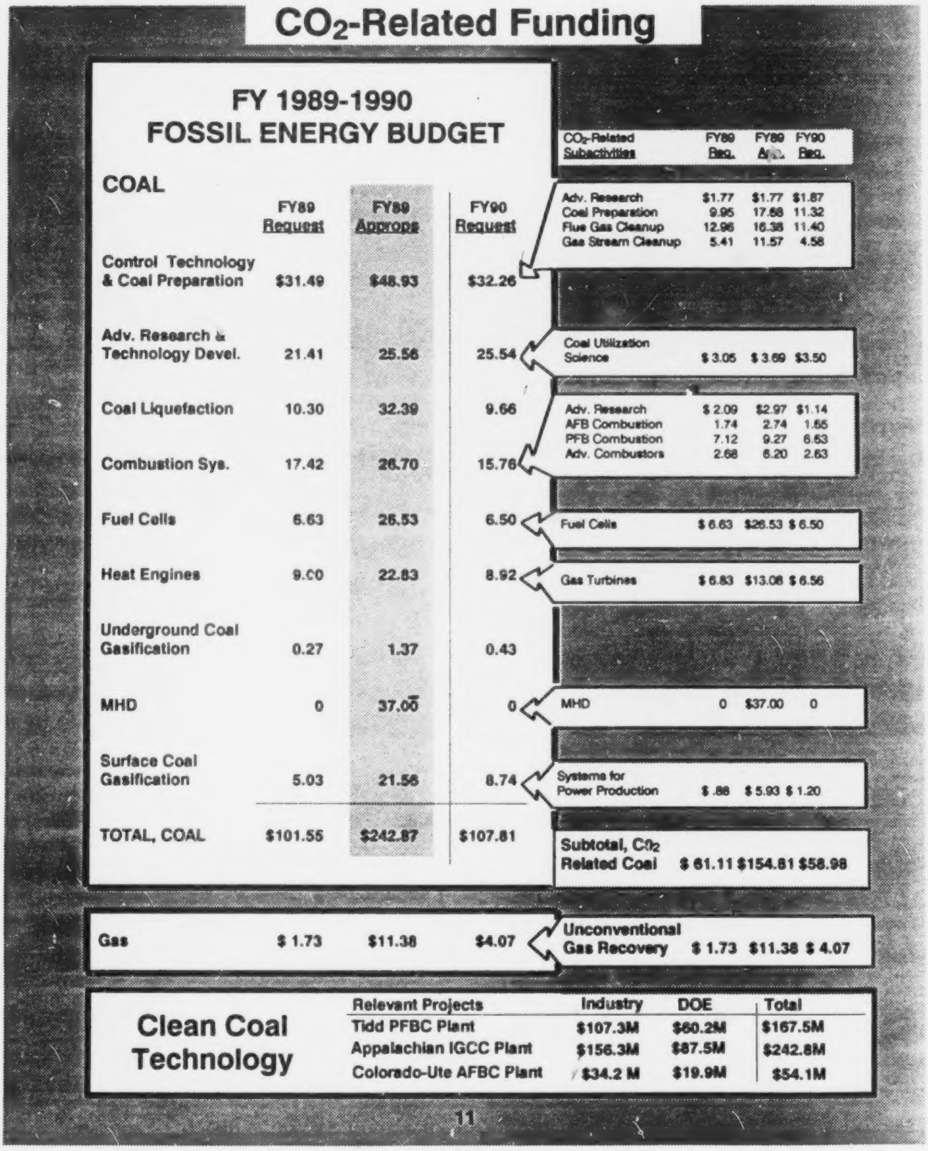
Nevertheless, if the scientific evidence ultimately shows that actions are necessary to mitigate global climate change, technology modernization can keep us from having to resort to regulation — and the usual stagnation caused by regulatory approaches.

The FY 1990 Fossil Energy budget contains several programs designed to develop modernized coal technologies with increased efficiencies over present processes, which could thereby reduce all combustion emissions, including carbon dioxide, per unit of energy produced. For example:

- Advanced coal technologies, such as pressurized fluidized bed technology and gasification-combined cycle, that offer power generation efficiencies in the 40-45 percent range (compared to 30-35 percent for conventional plants) can reduce CO_2 emissions by 10-15 percent.
- New flue gas cleanup and other pollution control methods that don't force overall reductions in power plant efficiency (such as is the case with today's scrubber technology) can be used to reduce other pollutants without adding to the amount of CO_2 released per unit of energy.

In addition, research into new recovery techniques for unconventional gas can ensure that the nation continues to have long-term supplies of natural gas, which emits about one-half as much CO_2 as coal per unit of energy produced.

The requested Fossil Energy funding that applies to these CO_2-mitigating technologies is shown by the chart on the next page.



CO_2-Related Funding

FY 1989-1990 FOSSIL ENERGY BUDGET

COAL

	FY89 Request	FY89 Approps	FY90 Request
Control Technology & Coal Preparation	$31.49	$48.93	$32.26
Adv. Research & Technology Devel.	21.41	25.56	25.54
Coal Liquefaction	10.30	32.39	9.66
Combustion Sys.	17.42	26.70	15.76
Fuel Cells	6.63	26.53	6.50
Heat Engines	9.00	22.83	8.92
Underground Coal Gasification	0.27	1.37	0.43
MHD	0	37.00	0
Surface Coal Gasification	5.03	21.56	8.74
TOTAL, COAL	$101.55	$242.87	$107.81
Gas	$ 1.73	$11.38	$4.07

CO_2-Related Subactivities	FY89 Req.	FY89 App.	FY90 Req.
Adv. Research	$1.77	$1.77	$1.87
Coal Preparation	9.95	17.88	11.32
Flue Gas Cleanup	12.96	16.38	11.40
Gas Stream Cleanup	5.41	11.57	4.58
Coal Utilization Science	$ 3.05	$ 3.69	$3.50
Adv. Research	$ 2.09	$2.97	$1.14
AFB Combustion	1.74	2.74	1.65
PFB Combustion	7.12	9.27	6.63
Adv. Combustors	2.68	6.20	2.63
Fuel Cells	$ 6.63	$26.53	$ 6.50
Gas Turbines	$ 6.83	$13.08	$ 6.56
MHD	0	$37.00	0
Systems for Power Production	$ .88	$ 5.93	$ 1.20
Subtotal, CO_2 Related Coal	**$ 61.11**	**$154.81**	**$58.98**
Unconventional Gas Recovery	**$ 1.73**	**$11.38**	**$ 4.07**

Clean Coal Technology

Relevant Projects	Industry	DOE	Total
Tidd PFBC Plant	$107.3M	$60.2M	$167.5M
Appalachian IGCC Plant	$156.3M	$87.5M	$242.8M
Colorado-Ute AFBC Plant	$34.2 M	$19.9M	$54.1M

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Alternative liquid fuels. The FY 1990 budget funds several programs designed to increase options for liquid fuels. With U.S. oil imports rising beyond the 40 percent mark (of total oil consumption), the most pressing national energy need is to ensure that we maintain an adequate and secure supply of liquid fuels.

As the chart on the next page shows, the FY 1990 Fossil Energy budget request contains $56.84 million for projects that can expand our liquid fuel options. This represents 34 percent of the total Fossil Energy R&D budget request. (For comparison, the FY 1989 budget request contained $39.65 million for liquids-related research, or approximately 24 percent of the total R&D budget request.)

In addition, as the chart indicates, two of the Round #1 Clean Coal Technology projects, with a total estimated value of more than $295 million, can contribute directly to increasing our domestic supply of liquid fuels.

Western coal initiatives. The FY 1990 budget contains several initiatives that can boost prospects for increasing the use of coal in the West and for increasing U.S. western coal export opportunities.

The U.S. has several hundred years of coal supply in deposits found throughout the country. Eastern coals, primarily bituminous and anthracite coals, today represent 70 percent of all coal mined in the U.S. and 90 percent of all coals exported. Much of the Department's coal-related budget is aimed at increasing the attractiveness — particularly from an environmental standpoint — of using eastern coals.

Western coals — subbituminous coals and lignites — are naturally low in sulfur content, yet suffer from low heating values because of their high ash and moisture content. Their high alkali content also can lead to boiler fouling and increased plant operating costs. Yet, these coals represent more than half of the demonstrated U.S. coal reserve base and offer the potential for meeting increasing demands for power in the western region of the U.S. as well as in burgeoning overseas markets along the Pacific Rim and elsewhere.

In the FY 1990 budget, the Department has included several initiatives intended to bring the knowledge base for western coals up to the same level as that of eastern coals. Two strategies are being pursued:

1) to develop technologies that could help expand coal use in the West. For example, one initiative in the FY 1990 budget request would study the use of western coals in diesel engines, which could help reduce the Western railroad industry's use of imported oil. Another initiative would involve the study of special wastewater treatment techniques and reflects the need to understand better the unique aspects of dealing with chemical constituents that differ considerably from those of eastern coals. Additionally, efforts are underway in mild

Liquids Funding

Liquids from Coal

FY 1989	Request Amount	Request % of Total Request	Approps
Liquefaction	7.06	4.20%	25.49
Gasification	.83	0.49%	11.59
Coal Slurries (Alt. Fuels/Coal Prep.)	13.74	8.18%	23.20
AR&TD			
Bioprocessing	0	0%	1.02
Liquefaction	0	0%	6.90
Surface Coal Gas.	0	0%	2.68
Subtotal (from coal)	$21.63	12.87%	$70.88

FY 1990 Request	Amount	% of Total Request
Liquefaction	$6.56	3.97%
Gasification	6.04	3.66%
Coal Slurries (Alt. Fuels/Coal Prep.)	$15.03	9.10%
AR&TD		
Bioprocessing	.21	0.13%
Liquefaction	3.10	1.88%
Surface Gas.	.65	0.39%
Subtotal	$31.59	19.13%

Other Liquids

Enhanced Oil Rec.	$16.98	10.11%	$23.58
Oil Shale	1.04	0.62%	10.53
AE&PT	0	0%	4.20
UGR (Gas to Liquids)	0	0%	1.21
Subtotal (Other)	$18.02	10.73%	$39.52

EOR	18.24	11.04%
Oil Shale	1.68	1.02%
AE&PT	4.62	2.80%
UGR (Gas to Liquids)	0.35	0.21%
Subtotal	24.89	15.07%

Total liquids $39.65 23.60% $110.40 — $56.48 34.20%

(FE R&D Request: $ 168.00) — (FE R&D Request: $165.21)

Clean Coal Technology

	TOTAL	DOE	INDUSTRY
Ohio-Ontario Coal Oil Co-Processing	$225.67	$45.00	$189.67
Energy Int. Underground Coal Gasification	$ 70.12	11.79	58.32
Subtotal (Clean Coal Tech. Liquids)	$295.79	$56.79	$247.99

gasification, which could convert western coals to more valuable liquid, gaseous and solid fuels; and

2) to accelerate efforts to open new markets for western coals internationally, especially in the Pacific region. This would be implemented by providing U.S. coal producers and technology developers with information they can use to market their products abroad, as well as by attempting to link advanced coal drying and mild gasification processes to the export of western coals. DOE will also begin consultations with industry to determine if an appropriate role exists for the government in the research and development of coal transportation alternatives for western coals.

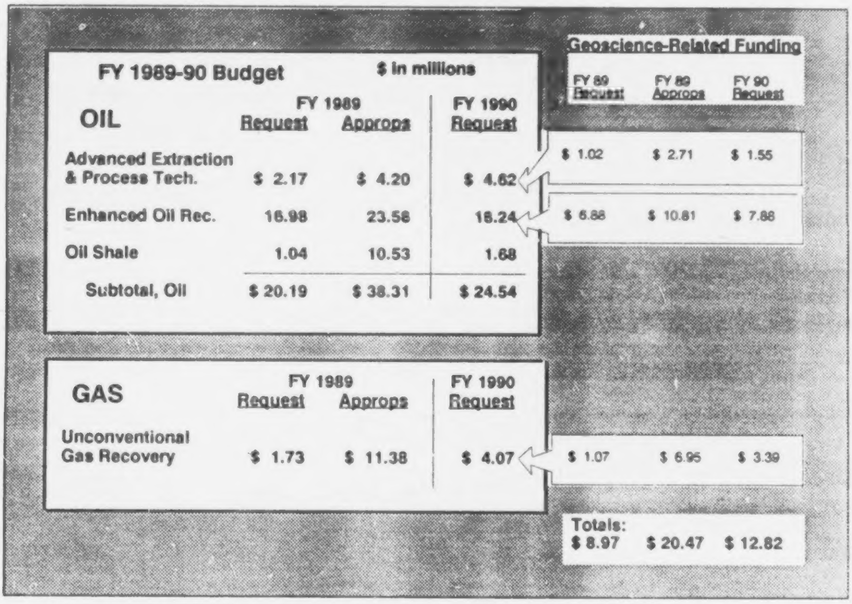
- **The FY 1990 budget continues support for oil and gas research with an emphasis on technology transfer to the independent producer.**

The FY 1990 fossil energy budget also maintains funding for vital research that can extend our domestic supplies of petroleum and natural gas. The U.S. has roughly 300 billion barrels of oil in known reservoirs that cannot be recovered with currently available technology at today's energy prices. This massive energy resource — more than 10 times the currently producible U.S. oil reserves — will require a better understanding of reservoir geology and fluid movement as well as the development of new, innovative recovery techniques. Significant potential also exists for *secondary gas recovery*, i.e., the production of natural gas that may have been bypassed or missed by conventional production techniques. The FY 1990 budget request contains funding to pursue both of these untapped hydrocarbon resources, as the following describes:

Petroleum. The FY 1990 petroleum-related budget, contained in two line items *Advanced Exploratory and Process Technology* and *Enhanced Oil Recovery,* continues to implement many of the research priorities outlined in the Department's "Enhanced Oil Recovery (EOR) Initiative" published last year after wide consultation with industry, state and academic petroleum experts.

As the "Enhanced Oil Recovery Initiative" described, the currently unrecoverable oil resource in the U.S. is made up not only of traditional EOR targets (i.e., *immobile* oil resources that require the injection of heat, gases or chemicals to move oil through the reservoir) but also significantly large supplies of *mobile* oil resources that may have been bypassed because oil reservoirs are not homogeneous. These mobile oil resources, existing in subtle traps or "reservoir envelopes" or otherwise isolated by barriers to fluid flow, may not require extensive EOR measures. Instead, a better understanding of the reservoir geology can lead to more predictable improvements in conventional primary and secondary recovery operations.

Therefore the FY 1990 budget places a substantial emphasis on geoscience-related research. DOE has also encouraged the formation of geoscience-oriented consortia involving university, state agency and private organizations. While the geoscience projects are managed and conducted as an inherent part of the petroleum and gas programs, they are overseen by a newly-created Office of Geoscience Research, reporting directly to the Assistant Secretary for Fossil Energy. The geoscience-related funding for oil and gas related research is shown by the following chart:



FY 1989-90 Budget — **$ in millions**

OIL	FY 1989 Request	FY 1989 Approps	FY 1990 Request
Advanced Extraction & Process Tech.	$ 2.17	$ 4.20	$ 4.62
Enhanced Oil Rec.	16.98	23.58	18.24
Oil Shale	1.04	10.53	1.68
Subtotal, Oil	$ 20.19	$ 38.31	$ 24.54

GAS	FY 1989 Request	FY 1989 Approps	FY 1990 Request
Unconventional Gas Recovery	$ 1.73	$ 11.38	$ 4.07

Geoscience-Related Funding

FY 89 Request	FY 89 Approps	FY 90 Request
$ 1.02	$ 2.71	$ 1.55
$ 6.88	$ 10.81	$ 7.88
$ 1.07	$ 6.95	$ 3.39
Totals: $ 8.97	$ 20.47	$ 12.82

Complementing the more fundamental geoscience research, the Department's FY 1990 petroleum budget also includes funding for both heavy and light oil recovery techniques. In the heavy oil program, research would continue on ways to increase the sweep efficiency of steamfloods and on new techniques for alkaline flooding. Novel extraction methods for presently unrecoverable heavy oil resources would be explored, as would advanced methods for restimulating mature wells, conducting oxygen-fueled firefloods, and injecting heat more efficiently into heavy reservoirs. Cooperative efforts with Venezuela in reservoir characterization also would receive funding in FY 1990.

In the light oil program, a wide range of both in-house and cost-shared research would take place to improve current CO_2-injection techniques, including a study of the merits of using CO_2 mobility control concepts on the North Slope of Alaska.

Also in the light oil research program, laboratory and field tests would continue in the area of microbial enhanced oil recovery, including a newly commissioned field test to be conducted in conjunction with the University of Oklahoma.

To assist in carrying out many of the petroleum-related programs, the Department has also established a site office in Metairie, Louisiana. The new office will serve as the focus of hydrocarbon research and development programs for the southeastern region of the U.S. The director and initial staff of this office are now in place.

Gas-Related Research. The Department is also proposing funding to conduct high-priority gas-related research projects. With major field experiments now completed in programs involving tight sand formations in the West and eastern gas shales in the East, the largest proportion of gas-related research is being directed toward an intense study of *secondary gas recovery*. A DOE-sponsored study last year, conducted by a panel of gas experts, identified enough natural gas in the lower-48 states to meet current demand for 35 years at costs below $3.00 per thousand cubic feet. Of the nearly 600 trillion cubic feet of gas estimated by the panel to be in this cost range, nearly 60 trillion cubic feet was included in the secondary gas category; that is, gas in bypassed reservoirs, in untapped compartments, or in deep pools that could have been missed by conventional production method. Last year, DOE provided a grant to the University of Texas Bureau of Economic Geology to verify the existence of this gas and the best means for producing it.

The Department has oriented its gas research program to complement the efforts sponsored by the Gas Research Institute (GRI), the privately-supported research arm of the gas industry. GRI, for example, will manage the secondary gas recovery project. In all, GRI will finance more than $170 million of gas-related research this year.

Technology Transfer. The budget request reflects a major emphasis on establishing mechanisms for transferring the results of federally-sponsored research to the private sector. Special emphasis has been given to negotiating cooperative exchange agreements with state governments (13 such agreements are now in place), both as a way of leveraging federal research funds and providing a mechanism for transferring the results of federally-sponsored research to the private sector. In the oil program, specific initiatives have been undertaken to transfer technology especially to the 24,000 independent oil producers who conduct virtually no research themselves. Particular emphasis in this area involves cooperative efforts through the Interstate Oil Compact Commission, the Western Research Institute and the national laboratories (the latter involving the transfer of unclassified, defense-related technology for use in locating and recovering oil and gas supplies).

More detailed information on each of the Fossil Energy research and development activities is included in the following program fact sheets.

COAL RESEARCH AND DEVELOPMENT

Control Technology and Coal Preparation

	Dollars in Millions		
Funding Activities	**FY 1988**	**FY1989**	**FY1990**
Advanced research	**$ 2.0**	**$ 1.8**	**$ 1.9**
Coal Preparation	**15.8**	**17.7**	**11.3**
Flue Gas Cleanup	**14.5**	**16.4**	**11.4**
Gas Stream Cleanup	**9.9**	**11.5**	**4.6**
Waste Management	**1.4**	**1.5**	**3.1**
Total	**$ 43.6**	**$ 48.9**	**$ 32.3**

Background

- **Advanced Research,** generic and fundamental in nature, is conducted on processes used to separate constituents such as sulfur and nitrogen oxides in coal fuel streams before, during and after combustion.
- **Coal Preparation** is directed toward the development of advanced coal cleaning technologies that will reduce the ash and sulfur content of U.S. coal so that the product can be formulated into a high quality fuel that could replace oil and/or gas and reduce environmental emissions of suspected acid rain precursors from coal-fired power plants in both new and retrofit applications. Research is conducted in three broad areas: (1) physical treatment and cleaning; (2) chemical/biological pretreatment and cleaning; and (3) engineering support and ancillary operations.
- **Flue Gas Cleanup** addresses the removal of polluting contaminants from fossil fuel fired systems to meet current and projected environmental standards that inhibit the utilization of fossil fuels. Efforts focus on fundamental research of processes for the combined removal of NO_x, SO_x, and particulates, both for utility and industrial applications.
- **Gas Stream Cleanup** includes the technology for removal of contaminants from gasifier and combustor process streams prior to utilization in coal conversion systems. Both hardware and environmental protection are key concerns. Applications include PFB combustors, integrated gasifier combined cycle (IGCC) turbines, direct coal-fired turbines, coal-fueled diesels, and liquid fuel production.
- **Waste Management** focuses primarily on waste sampling and characterization from coal preparation and emerging technology wastes.

FY 1990 BUDGET	Dollars In Millions
Advanced Research	
– Increase generic research on acid rain precursors and their removal. Examine the surface properties of coal and coal minerals. Continue studies of SO_x/NO_x separation processes and the effects of process filtration processes. (FY 1989 - $1.8M)	$1.9
Coal Preparation	
– Initiate western coal drying research. (FY 1989 - $0)	0.5
– Continue research and explore new concepts for physical and chemical/biochemical coal cleaning. Continue research on technologies for controlling emissions from pre-NSPS utility boilers. (FY 1989 - $8.3M)	5.9
– Continue DOE/EPRI testing of most promising advanced concepts for fine coal cleaning. (FY 1989 - $2.2M)	0.5
– Continue high sulfur coal research program with the State of Illinois. (FY 1989 - $1.5M)	1.5
– Continue in-house research to investigate and evaluate advanced physical and chemical coal cleaning concepts. Continue organic sulfur chemistry studies. Characterize feedcoal and coal cleaning products, and study the role of surface functional groups in coal treatment. Continue program management support. (FY 1989 - $3.0M)	2.9
Flue Gas Cleanup	
– Continue research for TUNG scrubbing process. Participate in EPRI program of emissions control for electric power generating stations burning high-sulfur coals. Continue spray dryer and in-duct technology development and systems integration studies for low cost duct injection. (FY 1989 - $5.8M)	4.6
– For combined NO_x/SO_x control, continue advanced NO_x/SO_x chemistry research, systems modeling, and economic evaluation. Continue development of advanced separation, evaluation of the moving-bed cop-	5.0

FY 1990 Budget (con'd)	Dollars in Millions
per oxide process, and large scale development of NO_x/SO_x processes. (FY 1989 - $7.4M)	
– Continue advanced NO_x control research, larger scale tests of fine particulate control in coal-fired boilers, research on emissions control from small scale boilers, and provide for technical and program management support. (FY 1989 - $2.4M)	1.8
• **Gas Stream Cleanup**	
– For Integrated Gasification Combined Cycle, continue development of novel sorbents and sorbent reactors. Commission a desulfurization system for a gasifier test facility. (FY 1989 - $3.8M)	1.8
– For Direct Coal-Fired Turbines, continue development of acoustic agglomeration, sulfur/particulate removal, and integrated low emissions concepts. Design cleanup equipment for METC combustor. (FY 1989 - $2.2M)	1.7
– Conduct systems analysis, membrane development, and program management support. (FY 1989 - $2.3M)	1.1
• **Waste Management**	
– Conduct wastewater treatment R&D for western coal processing. (FY 1989 - $0)	1.9
– Continue multi-site field monitoring of disposed wastes; geochemical and geotechnical analysis of wastes; characterization of wastes; waste-related data base maintenance; and program management support. (FY 1989 - $1.4M)	1.2
Total, Control Technology and Coal Preparation	**$ 32.3**

Advanced Research and Technology Development

Dollars in Millions

Funding Activities	FY 1988	FY1989	FY1990
Coal Utilization Science	$ 4.5	$ 3.7	$ 3.5
Materials & Components	8.5	8.5	6.4
Technology Crosscut			
Environmental Activities	2.4	2.6	2.5
Technical & Economic Analyses	1.5	2.0	2.7
Exploratory Tech. Base Res.	0.0	0.0	2.4
Coal Technology Export	0.0	0.0	2.4
International Program Support	0.0	0.8	0.7
Instrumentation & Diagnostics	1.5	1.5	1.3
Bioprocessing of Coal	1.0	1.0	0.2
University Coal Research	5.5	5.5	3.8
Total	$ 24.9	$ 25.6	$25.6

Numbers may not add due to rounding

Background

- The Advanced Research and Technology Development (AR&TD) Program is directed toward removing the inherent scientific and engineering barriers in generic technical areas that may hinder the development of all fossil energy technologies.
- The coal science program focuses on mission-oriented fundamental research which will lead to coal utilization systems that offer substantial improvements in efficiency, reliability and environmental performance.
- The AR&TD program includes generic studies of materials and components, investigations of instrumentation concepts in environments associated with advanced coal technologies, and exploratory research with high payoff potential for major advances to enhance greater use of coal in the U.S.
- The technology crosscut program undertakes management and scientific studies and research relating to several crosscutting areas relating to fossil fuel technologies.

FY 1990 Budget	**Dollars in millions**
• Coal Utilization Science	
– Continue generic studies of coal properties and the underlying chemistry and physics of coal utilization	$ 3.5

processes. Includes research on surface science pertaining to coal beneficiation; combustion science pertinent to boilers, heaters, heat engines, gas turbines and fluidized beds; separation science pertinent to SO_x/NO_x, particulate and trace element pollutant removal; and waste characterization. Continue to fund technical and program management support. (FY 1989 - $3.7M)

- **Materials**
  - Continue research on structural ceramic composites, microwave sintering, advanced austenitic alloys, advanced aluminides, ceramic membranes, ceramic catalyst supports, mechanisms of erosion and corrosion, solid oxide fuel cell materials, and studies of the formation and breakdown of protective oxide scales. Continue to fund technical and program management support. (FY 1989 - $6.5M) 5.0
- **Components**
  - Continue activities to develop novel components for advanced coal technologies, fundamental research on solids transport, and continue to fund technical and program management support. (FY 1989 - $2.0M) 1.4
- **Environmental Activities**
  - Continue analyses of issues associated with air and water quality, solid waste disposal, and toxic substances. Continue support of occupational health, quality assurance, and safety compliances services. Continue research conducted under NAPAP with emphasis on quality assurance of data and analytical tools. (FY 1989 - $2.5M) 2.5
- **Technical & Economic Analyses**
  - Continue generic studies supporting multi-year planning, FE strategy and program formulation; conduct contract studies that crosscut a number of FE programs, fund IEA/Coal Research Service activities. (FY 1989 - $2.0M) 2.7

FY 1990 Budget (con'd)	Dollars in Millions
• **Exploratory Technology Base Research**	
– Fund joint government-industry cost-shared research at Western Research Institute and the University of North Dakota Energy and Minerals Research Center (FY 1989 - $0.0M)	2.4
• **International Program Support**	
– Conduct analyses, studies and technical evaluations of the IEA and bilateral agreement activities in which the FE program is involved and provide technical and logistic support for international collaborative fossil energy research. (FY 1989 - $0.8M)	0.7
• **Coal Technology Export**	
– Provide support for coal technology export and linkage studies, coal and coal technology programs and promotion initiatives, Less Developed Countries Coal/Technology Export project identification, prefeasibility and project initiatives, and U.S./Italy project on Superclean Coal Water Slurries. (FY 1989 - $0.0M)	2 [illegible]
• **Instrumentation and Diagnostics**	
– Investigate in-situ instruments and develop spectroscopic techniques to identify molecular species and to provide process control in hot gas streams. Characterize coal liquid slurry atomization and develop novel viscosity measurement methods for coal slurry based combustion systems. Investigate fiber optics technology, explore instrumentation techniques for densely loaded streams, provide crosscutting instrumentation system information, and fund technical and management support. (FY 1989 - $1.5M)	1.3
• **Bioprocessing of Coal**	
– Continue, at a reduced level of effort, research on bioprocessing of coal with emphasis on fundamental mechanisms of desulfurization and provide technical and management support. (FY 1989 - $1.0M)	0.2

FY 1990 Budget (con'd)	Dollars in Millions
• **University Coal Research**	
– Support approximately 22 new grants at universities on the ongoing research topics including coal science, reaction chemistry, surface science, advanced process concepts, thermodynamics, engineering fundamentals, and environmental sciences; continue encouragement of collaboration between university and industrial researchers. Provide for technical and management support. (FY 1989 - $5.5M)	3.8
Total, Advanced Research and Technology Development	$25.6

Coal Liquefaction

	Dollars in Millions		
Funding Activities	**FY 1988**	**FY1989**	**FY1990**
Advanced Research	$ 6.1	$ 6.9	$ 3.1
Direct Liquefaction	13.4	17.3	2.9
Indirect Liquefaction	6.6	6.6	2.7
Support Studies/Engineering Evaluations	1.0	1.6	1.0
TOTAL	$27.1	$32.4	$9.7

Background

- This program supports basic and applied research to develop advanced technology for the production of synthetic liquid fuels from coal. The Department focuses upon two approaches to produce liquid fuels from coal, direct liquefaction and indirect liquefaction.

FY 1990 Budget	Dollars in Millions
• **Advanced Research**	
– Continue research on: novel catalytic, biological and other approaches to coal liquefaction; improving the understanding of liquefaction processes; and, on	$ 3.1

FY 1990 Budget (con'd)	Dollars in Millions
physical, chemical and thermodynamic properties of fossil fuel liquids. Continue to fund technical and program management support. (FY 1989 - $6.9M)	
• **Indirect Liquefaction**	
– Continue laboratory research at PETC investigating catalysts/reactor systems to efficiently convert coal derived gaseous feedstocks to gasoline, diesel, or jet fuels. Maintain limited laboratory research with industry and universities on alcohol and hydrocarbon fuel process concepts. (FY 1989 - $6.6M)	2.7
• **Direct Liquefaction**	
– Continue PETC in-house research. Continue laboratory research in co-processing. Maintain limited research on staged catalytic liquefaction. (FY 1989 - $17.3M)	2.9
• **Support Studies/Engineering Evaluations**	
– Maintain process stream characterization research for advanced coal liquefaction and co-processing processes. Continue novel catalyst development and process studies at Sandia National Lab. (FY 1989 - $1.6M)	1.0
Total, Coal Liquefaction	$ 9.7

Combustion Systems

Funding Activities	FY 1988	FY1989	FY1990
Advanced Research	$ 3.4	$ 3.0	$ 1.2
Atmospheric Fluidized Bed	2.4	2.7	1.7
Pressurized Fluidized Bed	7.2	9.3	6.6
Advanced Combustion Tech.	3.5	6.2	2.6
Alternative Fuels Utilization	3.7	5.5	3.7
Limestone Injection Multi-Stage Burners	5.0	0.0	0.0
TOTAL	$25.2	$26.7	$15.8

Background

- The Department of Energy has developed a program to increase the contribution and application of the nation's coal resources through the development of acceptable combustion systems and fossil-derived fuels for the marketplace. The programs within the overall Combustion Systems activity are: Advanced Research, Atmospheric Fluidized Bed, Pressurized Fluidized Bed, Alternative Fuels and Advanced Combustion Technology. Funding for the LIMB program, conducted by EPA, was also part of this activity.

FY 1990 Budget	**Dollars in Millions**
• **Advanced Research**	
– Continue generic studies to examine the fundamental aspects of combustion mechanisms, engine combustion design, corrosive behavior and deposition of combustion products. (FY 1989 - $3.0M)	$ 1.2
• **Atmospheric Fluidized Bed Combustion**	
– Continue to conduct in-house experimental and analytical erosion studies and AFBC development efforts. (FY 1989 - $0.5M)	0.5
– Initiate proof-of-concept testing within the Advanced Concepts Program. (FY 1989 - $0.7M)	0.4
– Continue subsystem development testing within the Special Applications Program. (FY 1989 - $1.0M)	0.4
– Continue low rank coal studies at UNDEMRC. (FY 1989 - $0.5M)	0.1
– Initiate cooperative research with WRI. (FY 1989 - $0.0M)	0.3
• **Pressurized Fluidized Bed Combustion**	
– Initiate advanced second generation PFBC systems component research efforts. (FY 1989 - $0.0M)	0.2
– Continue modeling studies and mechanisms for tube wastage alloys for long term testing. Provide technical and program management support. (FY 1989 - $0.9M)	0.6
– Continue research efforts at METC on PFB dynamics, systems analysis and combustion characterization, technology and economic analysis assess-	1.7

FY 1990 Budget (con'd)	**Dollars in Millions**
ment, evaluation of alternate advanced PFB systems and low rank coal listing at UNDEMRC. (FY 1989 - $1.9M)	
– Continue Advanced Concepts Phase II development and proceed with phase III, if appropriate. (FY 1989 - $4.5M)	4.1
– Continue Hot Gas Clean-up Test Stream design evaluations for installation at TIDD PFB Demonstration Plant. (FY 1989 - $2.0M)	0.0
• **Advanced Combustion Technology**	
– Continue development of the most promising advanced combustion systems for industrial, utility, commercial and residential applications. (FY 1989 - $5.2M)	1.8
– Continue in-house activities on combustion enhancement and pollution suppression research including data base development for technology transfer to the private sector. Continue to provide technical and program management support. (FY 1989 - $1.0M)	0.8
• **Alternative Fuels Utilization**	
– Complete formulation and characterization of coal-based fuels in support of the advanced combustion systems program. Continue transport, handling and storage studies, and combustion characterization of beneficiated coal based fuels. Continue project management support. Assess and test deeply beneficiated coals for retrofitting large pre-NSPS coal-fired boilers for acid rain control. Continue cooperative agreement with UNDEMRC. Provide technical and program management support. (FY 1989 - $5.5M)	3.7
Total, Combustion Systems	**$15.8**

Fuel Cells

	Dollars in millions		
Funding Activities	**FY 1988**	**FY1989**	**FY1990**
Advanced Research	**$ 1.5**	**$ 1.6**	**$ 1.0**
Phosphoric Acid Systems	**13.2**	**9.5**	**0.0**
Molten Carbonate Systems	**11.1**	**7.1**	**3.4**
Advanced Concepts	**8.4**	**8.3**	**2.1**
TOTAL	**$34.2**	**$26.5**	**$ 6.5**

Background

- The objectives of the Fuel Cells program are to support high risk, high payoff technology base development and to assist private industry in developing hydrocarbon fuel conversion technologies to improve the cost effective, efficient and environmentally acceptable use of conventional and alternative hydrocarbon fuels.
- Advanced research, fundamental and generic in nature, is conducted to better understand the basis of the underlying processes involved in fuel cell operation and to explore novel concepts and advanced materials.
- Phosphoric acid systems have reached a near-commercial technical status with large scale testing underway. The Department proposes that any further technology development of phosphoric acid fuel cells be the responsibility of the private sector.
- The technical feasibility of molten carbonate fuel cells operating at approximately 60 percent electrical conversion efficiency (natural gas to busbar) has been forecast by single cell testing. The complexity and associated capital costs of advanced fuel cell systems are projected to be less than those for first generation phosphoric acid fuel cell systems.
- The solid oxide fuel cell is an advanced, high temperature solid state fuel cell that offers promise in electric utility and in cogeneration applications in industrial and commercial sectors.

FY 1990 Budget	**Dollars in Millions**
• **Advanced Research**	$ 1.0
– Continue generic research in basic electrochemistry science. (FY 1989 - $1.6M)	

FY 1990 Budget (con'd)	**Dollars In Millions**
- **Molten Carbonate Systems**	3.2
– Complete the three ongoing coal-fueled molten carbonate fuel cell (MCFC) stack technologies leading to a new competitive action to select the most promising MCFC technology. (FY 1989 - $6.8M)	0.2
– Continue systems assessment of MCFC systems, and program management support. (FY 1989 - $0.3M)	
- **Advanced Concepts**	1.5
– Continue development of tubular solid oxide fuel cell (SOFC) technology for coal-fueled applications. (FY 1989 - $6.9M)	0.6
– Continue gasification/solid oxide fuel cell system analysis and materials characterization and development. Continue program management support. (FY 1989 - $1.4M)	
Total, Fuel Cells	**$ 6.5**

Heat Engines

	Dollars in millions		
Funding Activities	**FY 1988**	**FY1989**	**FY1990**
Gas Turbines	$ 11.0	$ 13.1	$ 6.5
Diesel Engines	7.0	9.7	2.4
TOTAL	$ 18.0	$ 22.8	$ 8.9

Background

- The principal goal of this program is to establish a technical data base through selected research which will enable the private sector to develop the technology needed for direct firing of coal and to assess the commercial viability of coal-fueled power conversion systems.

- The program focuses on key technical problems associated with substituting coal or coal-derived gaseous fuels for distillate fuels or natural gas in gas turbine and diesel power conversion systems.
- Applications for this technology include industrial cogeneration, combined cycle electric power generation, repowering of existing generating capacity, and power sources for both rail and marine transportation.
- The FY 1990 budget request for Heat Engines is believed to be appropriate given current fiscal constraints. It is not necessary to fund multiple approaches in this program area, particularly in times of funding limitations. We believe that funding the most advantageous technical approaches will still provide for a strong development activity.

FY 1990 Budget	Dollars in Millions
• **Gas Turbines**	
– Continue coal-fueled gas turbine integrated systems testing with one contractor. (FY 1989 - $9.7M)	$ 3.8
– Continue pressurized coal combustion testing, advanced combustion test facility fabrication, and systems analyses. Continue low rank coal activities and program management support. (FY 1989 - $3.4M)	2.7
• **Diesel Engines**	
– Continue coal-fueled diesel engine integrated system development with one contractor. Continue combustion testing and systems analysis, low-rank coal activities, and program management support. (FY 1989 - $9.7M)	2.4
Total, Heat Engines	$ 8.9

Underground Coal Gasification

	Dollars in Millions		
Funding Activities	**FY 1988**	**FY1989**	**FY1990**
Gasification Tech. Develop.	$ 1.7	$ 0.3	$ 0.2
Environmental & Adv. Research	1.1	1.1	0.2
TOTAL	$ 2.8	$ 1.4	$ 0.4

Background

- This program supports the development of viable technology for in situ conversion of coal to a cleaner burning, easily transportable gaseous fuel.
- Program efforts are directed toward the definition of technical, operational, and environmental parameters sufficient to allow industry to make decisions concerning the commercial development of the technology.

FY 1990 Budget	**Dollars in Millions**
· **Gasification Technology Development**	
– Continue cooperative research efforts with WRI. (FY 1989 - $0.3M)	$ 0.2
· **Environmental and Advanced Research**	
– Continue environmental compliance, restoration, and reclamation activities at historical UCG test sites as required by law. (FY 1989 - $1.1M)	0.2
Total, Underground Coal Gasification	**$ 0.4**

Magnetohydrodynamics

	Dollars in millions		
Funding Activities	**FY 1988**	**FY1989**	**FY1990**
Proof-of-Concept Topping Cycle	**$ 21.1**	**$ 24.1**	**$ 0.0**
Proof-of-Concept Bottoming Cycle	**8.4**	**8.8**	**0.0**
Proof-of-Concept Seed Regeneration	**0.9**	**0.2**	**0.0**
System Studies, Supporting Research & Conceptual Design	**4.6**	**3.9**	**0.0**
TOTAL	**$ 35.0**	**$37.0**	**$ 0.0**

Background

- The current FY 1989 MHD program continues the second year of the planned five-year proof-of-concept (POC) program which is based on the Department's June 1984 Coal-Fired MHD Preliminary Transition and Program Plan (and outlined in the FY 1988 MHD Program Plan). This program has been providing the design basis for the development of components and subsystems and furnishing the technology base for integrated, long duration, POC testing. Long duration POC testing would be needed for the advancement of the MHD technology to the retrofit demonstration stage which is a necessary prerequisite for subsequent commercial application.

FY 1990 Budget	**Dollars in Millions**
– No funds have been requested for FY 1990. Since it is estimated that $114 million (in constant FY 1988 dollars) is needed to complete POC testing, the Department believes that the cost of continuing its MHD program is not affordable in light of current fiscal constraints. (FY 1989 - $37.0M)	$ 0.0

Surface Coal Gasification

	Dollars in millions		
Funding Activities	**FY 1988**	**FY1989**	**FY1990**
Advanced Research	**$ 2.7**	**$ 2.7**	**$ 0.7**
Systems for Power Production	**11.2**	**5.9**	**1.2**
Systems for Industrial Fuel Gas Production	**1.4**	**0.9**	**0.8**
Systems for Synthesis Gas Production	**1.9**	**2.5**	**1.1**
Systems for Coproducts Production	**5.3**	**9.1**	**4.9**
Great Plains Coal Gasification Project	**0.5**	**0.5**	**0.0**
TOTAL	**$23.0**	**$21.6**	**$ 8.7**

Background

- The Surface Coal Gasification program is organized to foster the development of advanced gasifier systems for the production of: electric power, synthesis gas (for synthetic natural gas, indirect liquefaction, and chemical feedstocks), industrial fuel gas, and coproducts (simultaneous production of solids, liquids, and gases). This activity also provides for basic and fundamental research related to surface coal gasification processes including studies of reaction mechanisms and chemistry.

FY 1990 Budget	Dollars in Millions
• **Advanced Research**	
– Conduct work on product and precursor properties of condensible hydrocarbons and concepts for bulk gas separation. Continue coal gasification system assessment and modeling efforts, and conduct ash agglomeration studies in fluidized bed gasifiers. (FY 1989 - $2.1M)	$ 0.6
– Continue work on separating hydrogen from synthesized gas using ion exchange membranes. (FY 1989 - $0.5M)	0.1
• **Systems for Power Production**	
– Continue METC in-house sulfur kinetic studies and technical and program management support. (FY 1989 - $1.8M)	0.7
– Continue development and testing of hot desulfurization in an entrained flow reactor system for power generation. (FY 1989 - $1.4M)	0.5
• **Systems for Industrial Fuel Gas Production**	
– Continue operation of the fluidized bed reactor at METC as well as continuing support for the planning, implementation, and application of the gasification data base. Continue instrumentation research efforts. Provide technical and program management support. (FY 1989 - $0.9M)	0.8
• **System for Synthesis Gas Production**	
– Continue engineering and technical support for the joint DOE/GRI program. (FY 1989 - $0.5M)	0.2
– Continue development for hydrogen production from low rank coal. (FY 1989 - $0.8M)	0.5
– Continue systems analysis and model development efforts. Provide technical and program management support. (FY 1989 - $0.5M)	0.4

FY 1990 Budget (con'd)	Dollars in Millions
• **Systems for Coproducts Production**	
– Conduct mild gasification studies to establish a matrix of product yields and investigate product options for coal-based fuels from mild gasification. (FY 1989 - $8.1M)	3.2
– Evaluate advanced technologies for treating and upgrading low rank coals. (FY 1989 - $0.4M)	1.0
– Investigate pyrolysis of coal under mild gasification conditions and upgrading condensibles to marketable high value fuels. (FY 1989 - $0.0M)	0.4
– Continue modeling analysis and system analysis. Provide technical and program management support. (FY 1989 - $0.5M)	0.3
Total, Surface Coal Gasification	$ 8.7

PETROLEUM AND GAS

Advanced Extraction and Process Technology

	Dollars in millions		
Funding Activities	**FY 1988**	**FY1989**	**FY1990**
Arctic and Offshore Research	$ 0.4	$ 0.4	$ 0.0
Fundamental Geoscience and Extraction Research	2.0	2.7	1.6
Supporting Technology and Environmental Research	1.0	0.9	3.0
University Geoscience Research	0.0	0.2	0.0
TOTAL	$ 3.4	$ 4.2	$4.6

Background

- The Advanced Extraction and Process Technology (AEPT) program pursues new concepts to achieve major increases in efficiency and cost reduction of recovery techniques for oil, gas, and oil shale.

- The goals of this research program are: (1) to conduct fundamental research relevant to recovery of oil, gas and oil shale, (2) to pursue application of discoveries from unexplored new concepts which may achieve major increases in the recovery of oil, gas and oil shale resources, and (3) to develop a fossil energy-related knowledge base that will improve the economics of fossil fuel production in the Alaskan Arctic and U.S. offshore operations and will expand the reserves.

FY 1990 Budget	Dollars in Millions
• **Fundamental Geoscience and Extraction Research**	
– Continue research on geoscience and extraction technology and development of advanced instrumentation to measure reservoir characteristics and thermal fronts. (FY 1989 - $2.7M)	$ 1.6
• **Supporting Technology and Environmental Research**	
– Continue a program of fundamental studies including crosscutting research in petroleum chemistry focusing on structural characterization and determination of the structure-property relationship of heavy crude, intermediate product stream, product, and byproduct. (FY 1989 - $0.7M)	0.6
– Provide funding for joint government-industry cooperative research activities at Western Research Institute and the University of North Dakota Energy and Minerals Research Center (FY 1989 - $0.0M)	2.3
– Fund technical and program management support. (FY 1989 - $0.1M)	0.1
Total, Advanced Extraction and Process Technology	$ 4.6

Enhanced Oil Recovery

	Dollars in Millions		
Funding Activities	FY 1988	FY1989	FY1990
Heavy Oil	$ 3.7	$ 4.3	$ 4.1
Light Oil	9.9	16.7	14.1
Tar Sands	2.0	2.6	0.0
Pilot Ventures Program	1.0	0.0	0.0
TOTAL	$16.6	$23.6	$18.2

Background

- Enhanced oil recovery (EOR) represents technologies that can increase domestic oil production between now and the critical time when the nation will likely rely more extensively on synthetic fuels.
- There is a need for the Department of Energy to assist industry in obtaining a better understanding of the mechanisms and behavior of advanced and novel EOR processes that can lead to improved and new process concepts for the recovery of presently unrecoverable oil resources.
- Program concentration is also upon the development of advanced oil recovery techniques and on reservoir characterization as part of the Fossil Energy Geoscience effort.

FY 1990 Activities	Dollars in Millions
• **Heavy Oil**	
– Continue basic research in mobility control mechanisms of steamflood additives. Define the mechanisms by which foam increases oil recovery and develop analytical and numerical models. Develop relative permeability and capillary pressure data. (FY 1989 - $1.3M)	$ 1.6
– Continue cooperative research with Venezuela on petroleum reservoir characterization and recovery studies and conduct technical and analytical assessments related to geoscience and recovery technology. (FY 1989 - $0.5M)	0.5
– Continue a geoscience characterization program, research in novel extraction approaches to presently deemed unrecoverable, heavy oil resources, and fundamental studies of reservoir characteristics and injection fluid interactions. Provide program support. (FY 1989 - $2.5M)	2.0
• **Light Oil**	
– Continue a broad based program of research in light oil recovery techniques and conduct related planning, technical and analytical assessments. (FY 1989 - $4.2M)	4.2
– Continue a geoscience effort and reservoir characterization and related fundamental studies addressing	5.1

FY 1990 Budget (con'd)	**Dollars in Millions**
definition of reservoir structure and composition. (FY 1989 - $6.1M)	
– Continue microbiological studies and explore the feasibility of other novel methods of extraction of residual oil resources. (FY 1989 - $1.6M)	1.2
– Continue a research program to utilize CO_2 and other gas recovery methods in a variety of situations to promote the efficient, effective and predictable application of these techniques. (FY 1989 - $1.8M)	1.8
– Continue industry/state cooperative work to apply lab scale EOR concepts in mature fields. Develop retrofit technology to reduce stripper well costs. Provide program support. (FY 1989 - $3.0M)	1.8
Total, Enhanced Oil Recovery	$18.2

Oil Shale

	Dollars in Millions		
Funding Activities	**FY 1988**	**FY1989**	**FY1990**
Oil Shale Technology Base	$ 6.7	$ 7.5	$ 1.0
Environmental Mitigation	2.8	3.0	0.7
TOTAL	$ 9.5	$ 10.5	$ 1.7

Background

- Oil shale technology development involves the development of extraction and conversion processes designed to convert oil shale to various liquid fuels. The program focuses on basic research to systematically study the chemistry, kinetics, and emissions related to eastern and western shale processing.
- The Environmental Mitigation program attempts to improve the technological base that can reduce the economic and environmental constraints to industrial development of U.S. oil shale resources and can increase the amount of resources that may be used economically.

FY 1990 Budget

	Dollars in Millions
• Oil Shale Technology Base	
– Continue METC in-house research on kinetics with modeling support, development of system analysis capability, and applied studies. Fund WRI to perform characterization of reference shales. (FY 1989 - $7.5M)	$ 1.0
• Environmental Mitigation	
– Continue studies of mechanisms of pollutant generation and fate, process stream characterization, and development of an environmental data base. (FY 1989 - $3.0M)	0.7
Total, Oil Shale	$ 1.7

Unconventional Gas Recovery

	Dollars in Millions		
Funding Activities	FY 1988	FY1989	FY1990
Eastern Gas Shales	$ 2.3	$ 3.1	$ 0.3
Western Tight Gas Sands	3.3	3.3	0.3
Environmental and Advanced Research	4.9	5.0	3.5
TOTAL	$10.5	$11.4	$ 4.1

Background

- This program fosters the development of advanced technologies for the extraction of natural gas from currently unrecoverable gas resources by reducing the uncertainty surrounding the potential magnitude of the unconventional gas resources and the conditions under which they can be produced. The program will develop and improve extraction technologies only to the point where concepts are proven and economics established.

FY 1990 Budget

	Dollars in Millions
• Eastern Gas Shales	
– Continue limited in-house support for and update the predictive models associated with reservoir and	$ 0.3

FY 1990 Budget (con'd)	Dollars in Millions
stimulation performance; continue minimal systems studies in support of production strategies. (FY 1989 - $3.1M)	
• **Western Tight Gas Sands**	
– Continue limited in-house work with predictive reservoir and stimulation models; expand technical data base. Continue minimal systems analyses in support of production strategies and forecasts of regional production patterns in light of multi-well results. (FY 1989 - $3.3M)	0.3
• **Environmental and Advanced Research**	
– Continue in-house geologic, geophysical and geochemical efforts to study deep source gas generation potential for sediments subducted by plate tectonic convergence. (FY 1989 - $0.1M)	0.2
– Limit studies to determine problems with heavy oil reservoirs containing hydrates. Continue in-house research on gas hydrates and catalyst systems for converting natural gas to liquids. (FY 1989 - $2.4M)	0.9
– Continue secondary gas recovery program. (FY 1989 - $2.5M)	2.4
Total, Unconventional Gas Recovery	**$ 4.1**

MANAGEMENT AND OTHER BUDGET ITEMS

Program Direction and Management Support

	Dollars in millions		
Funding Activities	**FY 1988**	**FY1989**	**FY1990**
Headquarters Program Direction			
Salaries and Benefits	$ 9.1	$ 9.5	$ 8.5
Travel	0.5	0.5	0.4
Contract Services	3.1	6.2	0.2
ETC Program Direction			
Salaries and Benefits	$19.0	$18.6	$13.6
Travel	1.0	0.9	0.6
Contract Services	26.3	31.3	2.2
Federal Inspector for the Alaskan Natural Gas Transportation System	$ 0.2	$ 0.3	$ 0.3
TOTAL	$59.2	$67.3	$25.8

Background

This activity provides funding for salaries, benefits and overhead expenses for the management of FE programs at Headquarters and the Energy Technology Centers:

- The Headquarters staff is responsible for overall program direction which implements DOE policy and communicates that policy to the Energy Technology Centers, sets program objectives, develops program plans and evaluates alternative program strategies, develops and defends budget requests to the Office of Management and Budget and to the Congress, approves procurement plans, monitors work progress, evaluates projects, approves revisions in work plans as required to attain program goals, and supports the Office of Geoscience Research.
- The Energy Technology Centers support day-to-day project management functions for assigned programmatic areas including contract and National Laboratory monitoring, development and maintenance of project budget and procurement plans, and other activities related to program and site support.
- The Office of the Federal Inspector for the Alaska Natural Gas Transportation System is responsible for coordinating all Federal activities pertaining to the construction and initial operation of the pipeline. The Office of the Federal Inspector also enforces federal laws and permits, and monitors activities that affect the system.

FY 1990 Budget	Dollars in Millions
• **Headquarters Program Direction**	
– Provide funds for salaries and benefits of 125 FTEs at Headquarters. This staff implements and communicates policy to the ETC's, sets program objectives, develops program plans and evaluates alternative strategies; develops and defends budget requests; approves procurement plans, and monitors work programs. (FY 1989 - $9.5M)	$ 8.5
– Provide funds for support of the activities stated above. Both domestic and international travel is conducted. (FY 1989 - $0.5M)	0.4
– Provide for contractual services that are generic to the entire FE program. Included are items such as printing, computer services, technical support services, conferences, etc. (FY 1989 - $6.3M)	0.2
• **ETC Program Direction**	
– Provide funds for salaries and benefits of the ETC staff of 243 FTEs. Activities of the staff include contract and lab monitoring; development and maintenance of project, budget and procurement plans, and other activities related to program and site support. (FY 1989 - $18.6M)	13.6
– Provide funds for travel in support of the coordination of the above activities in the attainment of program goals, both domestically and abroad. (FY 1989 - $0.9M)	0.6
– Provide funds for facility operations, maintenance, finance and administrative support and other costs not appropriately chargeable to R&D projects, in support of this level of FTE's. (FY 1989 - $31.3M)	2.2
• **Federal Inspector for the Alaskan Natural Gas Transportation System**	
– Provide funds for administrative and support functions; continue to assess developments in U.S. and Canadian energy markets and maintain liaison with project sponsors, producers, other government agen-	0.3

FY 1990 Budget	Dollars in Millions
cies, State of Alaska and the Canadian government. (FY 1989 - $0.3M)	
Total, Program Direction and Management Support	**$25.8**

Plant and Capital Equipment

	Dollars in millions		
Funding Activities	**FY 1988**	**FY1989**	**FY1990**
Capital Equipment	**$ 0.5**	**$ 0.5**	**$ 0.0**
Construction	**17.7**	**21.2**	**1.9**
TOTAL	**$18.2**	**$21.7**	**$ 1.9**

Background

- Capital equipment is purchased annually to replace obsolete equipment so that the analytical capabilities are constantly being upgraded at the Energy Technology Centers (ETCs) and the National Laboratories.
- General plant projects are essential to the safe, efficient operation of the ETCs and construction is dedicated to a number of improvements, alterations and additions at each of the Energy Technology Centers.
- The major reduction between the FY 1989 appropriations and the FY 1990 request is primarily the result of the completion of the government's funding commitments for two Congressionally-added construction projects (at West Virginia University and the University of Oklahoma).

FY 1990 Budget	Dollars in Millions
• Construction	
– Continue construction of chemical engineering laboratories project at PETC. (FY 1989 - $1.3M)	$ 1.9
Total, Plant and Capital Equipment	**$ 1.9**

Environmental Restoration

Funding Activities	FY 1988	FY1989	FY1990
	Dollars in millions		
RCRA Remedial Actions	$ 0.0	$ 0.0	$ 0.0
CERCLA Remedial Actions	0.0	0.0	1.0
TOTAL	$ 0.0	$ 0.0	$ 1.0

Background

- In May 1983, the Pittsburgh and Midway Coal Mining Co. (P&M), the DOE contractor/operator of the Ft. Lewis Pilot Plant (Tacoma, Washington), was notified by EPA that, under the Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA), it was potentially liable along with hundreds of others, for cleanup of the Western Processing Site. The site was used for disposal of industrial waste from the Solvent Refined Coal pilot plant operated from 1974 to 1981.
- DOE, P&M and others have agreed to pay the costs of cleaning up the site and a trust fund has been established to receive and disburse payments.
- Total site cleanup (Phase I/Surface and Phase II/Subsurface) was estimated- to be a minimum of $40 million. Currently, cleanup is in Phase II and monitoring will not be complete until the year 2020.
- In May 1988, the Laramie Project Office received a Notice of Violation from the Wyoming Department of Environmental Quality. As a result of this Notice, the Department has agreed to assist in the cleanup of the Rock Springs site.

FY 1990 Budget	Dollars in Millions
– Fund DOE share of Ft. Lewis trust fund Phase II-cleanup of Western Superfund site. (FY 1989 - $0.0M)	$ 1.0
– Continue cleanup of the Rock Springs site including groundwater sampling and analyses, pumping and water treatment, well abandonment and reseeding using prior year funds. (FY 1989 - $0.0M)	0.0
Total, Environmental Restoration	**$ 1.0**

DISCUSSION

Mrs. **Lloyd**. Thank you very much, Allen.

Most of you in the audience know that Clean Coal Technology Demonstration Program calls for the Department of Energy to cost share with private industry the demonstration programs aimed at providing the feasibility of the new technologies which will allow us coal utilization in an environmentally-benign manner.

I believe that Department of Energy has made a very good beginning, as I mentioned earlier, in implementation of this demonstration program with Round One successfully negotiated.

Allen, would you discuss the recoupment provisions that were negotiated with the first round technologies, and discuss some of the problems that you found in the negotiations.

Mr. **Wampler** Our recoupment has certainly been an area of much discussion——

Mrs. **Lloyd**. I thought you'd like to talk about that.

Mr. **Wampler** [continuing]. In every hearing and public meeting that we've had on this subject.

The recovery of the government's contribution in this program is generally to come from the sum of the following potential revenue resources, the first being that revenues from operations of the project beyond the operating stage.

That particular provision has required very considerable discussion with the private sector about project objectives and length of operation.

The negotiation issues that we run into on a recoupment have generally focused on the definition of net revenue—what constitutes a net revenue, new terms, as net distributable revenue, became an area of discussions. And utilities had little or no opportunity to use as a source of repayment plan.

Another area of negotiation where proceeds from the commercial sale, lease, manufacture and licensing of the demonstrated technology.

The problem that we had in this particular was that if you look at the bidders in Clean Coal technology, they are a diverse group of equipment manufactured utilities. And there have been considerable arguments about who is paying the fair share of this recoupment.

We tried to move from an individually-negotiated recoupment provision in Round One to a recoupment provision that we provided for in Round Two that made recoupment more similar to deals of industry, estimate of striking with industry. For example, the licensing, fees for licensing, fees for that sort of thing.

We have, to this point, not negotiated any of those specifically in the Round Two projects. We expect them to be less problematic than the Round One issues were.

Mrs. **Lloyd**. Basically, it's been lesson learned that will help you in the next round.

Mr. **Wampler**. We think so very much.

Mrs. **Lloyd**. Very good.

Mr. **Wampler**. And we are currently looking again, even without the benefit of negotiating Round Two, at particular percentages that we're using to see if they are in line with what industry is accustomed to paying.

So it's an issue that we're continuing to look at. It has been problematic, but I think we've come a long way in it.

Mrs. LLOYD. You mentioned the Western coals in your testimony. Has there been criticism for the lack of Western projects?

Mr. WAMPLER. There has been criticism. The last round of projects selected, there was only one Western project selected in that group. And that was State of Texas.

We started an effort about three months ago to try to determine why we were getting fairly minimal Western interest. We had a public meeting in Cheyenne, Wyoming a couple of months ago that was very well-attended. As I recall, 130 people.

We had an additional meeting in Denver with about the same attendance. And as a result, we came up with the following reasons that we were not getting Western projects. The lack of host sites was one of the reasons.

The language of the Program Opportunity Notice, especially Clean Coal II, made it appear that the program was simply a high-sulfur pollution control technology program. We worked very hard to try to get the word out that Western projects were eligible, but we evidently were less than totally successful in doing that.

There are also limited State funding sources in the West. As you know, in the East, many States have passed bond issues that allows them to put money into the budget for government.

Mrs. LLOYD. What sort of response have you had from the utilities in project participation?

Mr. WAMPLER. Well, the utility responses is very, very encouraging. We were worried in Round One that we were getting less than perfect utility responses.

Mrs. LLOYD. What sort of technologies are they interested in participating with?

Mr. WAMPLER. Well, they're interested in participating in almost all the technologies. They're generally interested in the retrofit of NO_x and SO_x control devices. They're interested in the repowering projects—pressurized fluidized bed, the circulating fluidized bed.

And there's a lot of growing evidence, I might point out now, Madam Chairman, in our third round of meetings—we've had a series of meetings on Round number three—that there is a substantial utility interest.

And we evaluate this by the people that attend the meetings and the formal written requests we get for information.

So we think that many utilities are planning to participate in future solicitations.

Mrs. LLOYD. On the coal program, it's cut back over $135 million. And with the emphasis on utilization of coal in an environmentally-sound manner.

It was my hope that we could increase the funding in this area. I do have a great deal of interest in the linkage between the fossil energy R&D and the projects with the need for Acid Rain litigation.

Do you have any rough timetables on alternative technologies to today's wet scrubbers, such as fluidized bed, and ICCG?

Mr. **Wampler**. The timetables are admittedly rough. We have these projects, all of these technologies, in one form or the other of demonstration.

If I had to give a general answer, I would say that probably these technologies will be ready for deployment somewhere around the year 2000. Some of them will be ready prior to that.

And the reason the answer is certainly not firmer, it depends on several approaches that we take, the kind of timetable that we have for acid rain legislation, how many of these technologies, for example, are successful and cost-effective, because those are two different—I'd say, generally, they'll start being ready to deploy around the year 2000.

Mrs. **Lloyd**. It's my understanding there's a new pilot program for technology transfer from Los Alamos and Sandia.

Can we expand on programs such as this from our other Labs? For instance, Oak Ridge? I'd like to discuss this program.

Mr. **Wampler**. Okay. What we did with Los Alamos and Sandia was to take existing technology that has been developed primarily for our weapons complex, take existing technology without the development of any new technology, and start an effort with the private sector to transfer this technology to the private sector.

At all of our National Labs, we're finding we have incredible technology on the shelf and, especially in the fossil area, there are some seismic instruments and drilling instruments that are very applicable to the oil and gas industry now.

So we basically structured the program in cooperation with those two labs—and this is brand-new. It's only several months old—to start this kind of technology transfer of existing technology.

We're going to be in the process of looking at the other Labs to see what we have on—

Mrs. **Lloyd**. Very good.

Mr. **Wampler**. And we've had several meetings with all the Labs involved in this particular area.

Mrs. **Lloyd**. As you know, technology transfer is going to be one of the major thrusts of this Committee again this year, so I hope that you would seriously look at all avenues where there can be meaningful technology transfer from the Labs to the private sector.

We would like——

Mr. **Wampler**. We'll make a special effort to do that.

Mrs. **Lloyd**. Thank you.

Mr. Morrison.

Mr. **Morrison**. Al, just a question about balance.

Clean Coal technology seems to be way out in front of all the other fossil energy R&D programs combined.

Any concern at your level about this imbalance? And is it possibly reflecting the pressure that's been on our Presidents of late from our good friends from the North, in Canada?

Mr. **Wampler**. There is always concern on this balance issue. There admittedly is a lot of money going into Clean Coal technology, but I think you have to look at it from a couple of standpoints.

One is that there is a lot of government money going into it, but there's even more private sector money going into it. There has been a commitment now from two Presidents to Canada to address this issue from a technological standpoint.

If you look at the costs of an acid rain scenario that would provide only for the installation of scrubbers versus the $5 billion or $6 billion that will be spent on the Clean Coal Technology Program, the terms of magnitude are much, much less for the technological process development.

But, yes, we all know we have scarce federal funds. Any large program is ultimately probably going to have an effect on other programs. But we tried very hard to keep the two complementary but separated. We tried very hard to propose at least a core research program that made some sense.

Again, as I said before, just because a program is not in the budget does not mean it's a bad program. We simply have more good ones than we have available funds for.

Mr. MORRISON. I've also found it rather interesting through the years that budget requests in this whole fossil energy R&D area stay, oh, in many cases, about 25 percent of what we end up finally appropriating.

Are you sort of silently hoping that we're going to do it to you again? [Laughter.]

Mr. WAMPLER. I just would have difficulty giving you a yes answer to that. I think that it's important to note that there is a difference this year, however. The President has indicated that the terms of the budget are certainly negotiable with Congress within certain ranges.

And let me answer the question that way, instead of—it's a tough process we all go through annually on this budget, and I realize that.

But I think this year it was the President's indication that the terms of the budget were negotiable. I'm encouraged by that.

Mr. MORRISON. Well we're pleased with your progress, we're just not sure we could keep forcing this money on you. [Laughter.]

Mr. MORRISON. I'm interested in liquefaction. The notice that your request terminates that work at two of the facilities, could you describe where we are and are we really that close to a private enterprise pick-up on the subject area?

Mr. WAMPLER. We're looking at—as I indicated in my opening statement, we've made some real considerable progress, in fact, far better than we thought we were going to make on the coal-derived liquids from Wilsonville, in particular.

We're about at $30 to $35 a barrel, somewhere in that range. Now that's down from $60 a barrel a couple of years ago. We're still not at $16 a barrel, and I doubt seriously that there is going to be a new technological advance that gets us there.

We see some further progress that we might make now; at a pilot scale, not at a large testing scale.

If you look at Wilsonville, continued operation could provide some additional results and probably some more advances, particularly in the two-stage liquefaction technology.

The cost of operating that facility because of its size it's a pretty expensive facility and it's a budget constraint problem. But we're very encouraged at coal-derived liquids at $30 to $35 a barrel—further than we thought we could get.

Mr. MORRISON. That is encouraging. It will take OPEC a while to get there, but it probably will happen.

Madam Chairman, thank you. I'd like to make sure our people who specialize in this area get as much time as possible.

Mrs. LLOYD. Thank you, Mr. Morrison.

Mr. Smith.

Mr. SMITH. Thank you, Madam Chairman.

Mr. Wampler, during his address to the Joint Session of Congress on the budget recently, President Bush spoke in terms of specific tax incentives in the oil and gas industry.

When will the Administration either introduce legislation or sponsor legislation to accomplish its goals?

Mr. WAMPLER. I would expect, from all I know about the process that's going on, that it will be a fast process; as far as a hard, fast date, I simply don't know.

But I know that immediately after he made that statement, it was being worked on by the Treasury Department. We are providing input to the Treasury Department and I'm sure other agencies are also.

So it is on a fast-track.

Mr. SMITH. When you say "fast," you're talking in terms of days, weeks or months?

Mr. WAMPLER. Either, I suspect. It's just difficult to answer because the Treasury is the one that's controlling the process. They could probably give you a fairly definitive answer.

If I had to guess, I would say it would be in the process of weeks. But, again, that's just a guess.

Mr. SMITH. I hope you're right.

As we all know, natural gas is a clean and abundant source of energy. What will the Administration do specifically to increase the production and consumption of natural gas?

What's it going to do to follow up on President Reagan's Natural Gas Initiative?

Mr. WAMPLER. I think natural gas has got several things that really are going for it. As you mentioned, it's clean. We have a larger resource of natural gas than we thought we had in the past.

The public is getting more comfortable with the fact that we have a supply of natural gas. We have some transportation problems to overcome, but I think that the free market is going to almost overcome that.

I think, from the standpoint of the Department of Energy, what we're trying to do is to put together a plan. The Geoscience Coordinating Committee, that we have had in effect several months, has been working on a very aggressive research and development plan that includes natural gas. It will be a large component of it.

That will be finished in May or June. At that time, the Department will have integrated effort in oil and gas, both the geoscience areas.

So we plan to continue the research. There's some unconventional kinds of production techniques, drilling techniques, that we see a great deal of promise in. We're seeing a seven-fold increase from the drilling of horizontal wells, for example. So we plan to continue.

The research, we're also looking at something that I think is very interesting and has a lot of merit, and that's the possibility of pollution control by gas/firing with coal, the existing coal-plants coal-firing with gas up to 10 percent. It provides about, we think, a 1.2 million ton reduction in SO_x area. So all those different kinds of areas we're trying to take a very careful look at.

Mr. SMITH. A minute ago, you mentioned May or June. Is that when you expect the Administration to come up with a detailed plan for increasing the consumption of natural gas?

Mr. WAMPLER. No. The May or June will be a detailed research plan from the Department of Energy, just that component of it.

Mr. SMITH. Okay.

Mr. WAMPLER. I think the whole area and use of natural gas is going to be addressed throughout the first part of the Administration by several different processes.

I think, as we look at our acid rain strategy, for example, and that's high on the Administration's list, natural gas will be a component that's looked at in the deliberations on acid rain.

I think that, as we look at this coal-firing I just mentioned, that could be another component. I think it will take several components along with the tax package that we're talking about.

Mr. SMITH. Let me switch over from domestic to foreign. As you know, the United States now imports 42 percent of the fuel that it uses.

In your judgment, does that represent just a problem, or a real crisis? And in either case, what is the Administration going to do about it?

Mr. WAMPLER. I think it indicates a problem. I don't think it indicates a crisis due to a couple of facts. One is we've—since the last embargo that we've experienced—we've diversified our supply—tremendous diversification to more secure suppliers.

The second thing we have in place is that large strategic petroleum reserve of 561 million barrels that we have in the ground that we could put on the market in response to any kind of a cutoff.

But, I think, as those imports creep up, you have a problem from the standpoint of energy security as well as revenues going out of the country. So I think, yes, it is a problem. I think we have to look at ways to get at the resource that we have in this country.

I think we have to have better methods of enhanced oil recovery. I think we have to look at the tremendous problem of 85,000–90,000 or perhaps more stripper wells that are being shut in this country and they're not going to be able to be brought back on line. So——

Mr. SMITH. Let me ask a couple of follow-up questions. I'm not sure I agree with your analysis that it's just a problem and not a crisis.

Is it not true that we import more fuel now than we did during the embargo of the early seventies?

Mr. WAMPLER. Yes. It is true.

Mr. SMITH. And is it not true that were we to rely upon the strategic petroleum reserve, we would use up those barrels within two to three months time if that became our sole source of energy and had to replace the foreign fuel that we now import?

Mr. WAMPLER. If you had a total embargo cutoff, you've got from 90 to 120 day supply. But I think the important thing to note is that you've got the supply coming out of the Strait of Hormuz, which we would calculate to be the supply that's most at risk.

You've got about a million barrels a day, so you've got a 560-day supply of that in the strategic reserve.

But, you're right. If you had an entire cutoff, you're dealing with 90 days.

Mr. **Smith**. Well, given the facts that I just mentioned that you agreed with, doesn't that make the United States susceptible to blackmail? Or doesn't that threaten our energy security and, therefore, our national security?

Or isn't the United States in a position where that might occur? And if so, why isn't that a crisis situation?

Mr. **Wampler**. Well, again, Mr. Smith, I think it is a problem. I think it's a serious problem that gets more serious as imports go up.

But I don't think we're at the stage that under hardly any scenario, that we could expect a full cutoff of imports.

Mr. **Smith**. Yes, I don't—last question for you is:

In the fiscal 1989 Interior Appropriations bill, Congress enacted $18.3 million for geoscience research program to improve our understanding of the basis for enhanced oil recovery techniques.

At least five million of these funds were to be competitively-awarded to interested consortia, including the Geoscience Institute for Oil and Gas Recovery Research. An agreement was signed with DOE this past year, as I understand it.

What is the status of that Geoscience Research Program, particularly with regard to the funding of the consortia activities?

It's my understanding that the Department of Energy has not been as supportive as we were led to believe it was going to be last year.

Mr. **Wampler**. Well, pardon, let me say unequivocally that the Department of Energy is supportive both of the consortium out of the University of Texas at Austin, and there's another consortium out of the University of Wyoming.

Mr. **Wampler**. We have had some difficulty as we've gone through this process of the interpretation of the Interior Appropriations Act as to whether or not we could direct funding without competing it to either of those consortia.

The Department's taken a position on the Hill that we're in agreement to doing that. But, the Appropriations Committee has said to us that that was not our intent.

So the status of the—we, by the way, over the past several weeks have been working closely with University of Texas on this problem.

What we have done, we are getting ready to go on the street with what we call a PURDA. Geoscience PURDA. And we'll open that up for competitive bid. And as far as I know, the University of Texas, at Austin, the consortium, fully intends to bid on that PURDA.

Mr. **Smith**. So the Department and the Administration are very supportive of the Geoscience Institute. They're just waiting on the process?

Mr. **Wampler**. Yes, they are very supportive of it.

Mr. **Smith**. Okay. Thank you, Madam Chairman.

Mrs. **Lloyd**. Thank you very much, Mr. Smith. Mr. Traficant.

Mr. **Traficant**. Thank you, Madam Chairman.

Mr. Wampler, just a little bit from some of the questions Mr. Smith had posed, we're concerned about this tremendous import of fuel source. Yet, in oil shale, there is a dramatic cut that's projected in the budget that's been outlined here today.

We know there are tremendous reserves in Eastern oil shale that are relatively accessible. It seems that we've made a commitment in the past and now the Administration wants to deviate quite seriously, and they're projecting an 84 percent cut from that type of a technology.

And I think that is inconsistent with our rhetoric to try and reduce our dependence on foreign energy sources. And we've been spending money here to try and bring about a continuum of a program that seems to be, from the nature of this proposal, to be aborted.

Is there any explanation for that? Or are we playing with numbers here? Or, is the Department of Energy saying to us that we don't want to continue on a schedule of trying to reclaim and develop utilization of oil shale reserves?

Mr. WAMPLER. Mr. Traficant, I think that there is no doubt that oil shales will at some point in time in this country be a major contributor to our energy security.

You're right. The resource, both in the West, is huge. There has been a lot of money spent on oil shale. But, if you look back to times that the bulk of the monies were spent, we were looking at $32–33 oil. As we're looking at the processes that we have now, and somebody might be able to refine these figures a little bit better for you, but the numbers I've seen is that we're looking at $44–50 a barrel to extract the shale.

We're trying to continue a low level of research. We're doing some characterization. That's about $700,000. We're doing some in-house research. But we think we have the technology in oil shales to the point that once the price gets right, that companies will develop these on their own.

We've made a lot of technological advancement. And now it's just a matter at what price.

Mr. TRAFICANT. Do you believe that further funding of the oil shale R&D program won't bring about better and advanced technology? It would in fact even reduce the cost per barrel of that technology?

Mr. WAMPLER. It is very possible that we could reduce the price per barrel, but I guess in setting our budget priorities, we try to look at maximum federal bang for the dollar that we're spending.

And I think, you know, while in oil shale we've got some areas that we really need to look at in environmental mitigation, because it's going to be commercially available and we've got some environmental problems we have to solve. As far as putting large amounts of federal dollars into oil shale right now, we don't see that it would be cost-effective.

Mr. TRAFICANT. Another particular area. We've had Round One some pre-awards and some awards relative to certain projects and initiatives in Clean Coal. One of them was the potential project that would co-process high-sulfur, high-nitrogen coal with that of crude oil by-products, et cetera, produce a distilled form of petroleum that can be retrofitted and burned in power plants without damage to the environment.

I have several questions in that regard. First, briefly, without taking too much time from the Committee, what is the status of those types of initiatives and how are those projects going forward in meeting the requirement as set forward?

Mr. **Wampler**. I think you're referring probably specifically to the Ohio-Ontario Project.

Mr. **Traficant**. Ohio-Ontario Project.

Mr. **Wampler**. That particular project, the preliminary engineering and cost estimate has been completed on it. The process development unit, which is the smaller stage unit, is being operated to sustain some additional input design that we need. And they're also in the process of exploring alternative sites for that project around in that general area.

They're doing some pretty innovative things. There's a tremendous amount of companies and individuals involved in that process. They're looking at fuel suitability for utilities right at this point in time, to even try to get a utility involved directly in the demonstration project.

So we're working with them. They're moving along. We expect those issues to be resolved——

Mr. **Traficant**. That's my next question. With the given cost factors associated with these power plants and these utility producers and providers, they really don't have the hammer on them for about another 10 years to meet certain environmental criteria that's been set forth in certain planning stages by the Congress and the Administration.

So, in that regard, what type of initiatives are being made to try and encourage a commercial application of these technologies once that new fuel is designed? Are there some tax breaks or other incentives built in that would make it amenable to, number one, retrofit in behalf of these power plants?

And, number two, to purchase these types of shields?

What type of initiatives or program has the Department promulgated, or will they recommend or consider as far as that?

I mean, producing the fuel isn't the final result. We have to get someone to buy it. We have to make it palatable. What are our programs to do that?

Mr. **Wampler**. I think we can separate them roughly into three areas.

One of the major objectives of the demonstration program is to demonstrate these technologies or production of this fuel, in this case, in its commercial form. That means getting the cost of the process down as low as we can to make it attractive from an economic standpoint. That will not always get it because you and I both know if the cost is a little bit higher, there's not an incentive.

The second thing that we are currently looking at are some FERC incentives to create a situation that deployment of technologies would be able to take advantage, for example, for rapid amortization, some other things that FERC can do to encourage these to be deployed.

We currently are in a situation that we're going to be submitting those to FERC on a fairly rapid time frame. They're being reviewed now in the Administration, looked at again to make sure that we have everything in there that we need.

The third category, as we get into the structure of an acid rain program in this Administration, I think that you're going to be looking at a lot of market drivers. Some of the statements that the President has made indicate that.

I think we have to look at additional incentives to make sure that these are deployed from both an environmental standpoint and a cost-effective.

Mr. TRAFICANT. Would the Department, as far as retrofit be concerned, would the Department be opposed to an interest-free loan program that perhaps could be set up by Congress?

Mr. WAMPLER. That's something we haven't looked at. I'm hearing it as a new proposal. That's something we'd be glad to take a look at.

Mr. TRAFICANT. We plan in my office, I, myself, specifically, plan to put that in the form of a legislative initiative. We'd like for you to look at that.

Mr. WAMPLER. We'd certainly look at it.

Mr. TRAFICANT. Finally, my last question, not to belabor the panel:

What kind of money do you have for retrofit? And at what planning stages are you relative to our Clean Coal technology and utilization of those end-products for commercialization, applicable use?

Mr. WAMPLER. There will be, if you include the federal share of $2.5 billion, and if we stay on the same track that we are on now, we'll get somewhere in excess of $6 billion private and federal share that's put into this program over the next several years.

We have projects under various phases of development. I'd be glad to furnish you a package on those that shows you exactly where the technologies are. But we think that, generally, these technologies will be ready by around the year 2000, to start being deployed in large-scale into the private sector.

That time, again, could vary based on what legislative requirements we have and how good we do our job at getting the cost of these things down, or what kind of packages we put together for incentives for deployment.

Mr. TRAFICANT. I appreciate your direct responses. That's a little unusual at times from some of the people. We appreciate that.

I thank you for the time.

Mrs. LLOYD. Thank you, Mr. Traficant.

Mr. Schiff.

Mr. SCHIFF. Thank you, Madam Chair. But, due to a conflict, I just arrived, as you know, and I'll pass on questions.

Thank you.

Mrs. LLOYD. Thank you a lot.

Mr. Walgren.

Mr. WALGREN. Thank you, Madam Chairman. I apologize that I, too, have only just been able to get here through the traffic.

I guess immediately in my mind is the Clean Coal technology program and the efforts that are being made in my area at the Pittsburgh Energy Technology Center, and in the Morgantown Center as well.

And it's my understanding that this work is being assigned and being built up and yet we are at least not increasing the personnel commitment to managing that program.

We've gone through One Round, halfway through a second Round. And as I understand it, the responsibilities become more intensive. At some point, we're going to need to have more people involved in carrying out those responsibilities.

Can you address that?

Mr. **Wampler**. Sure, I'd be glad to, Congressman Walgren.

The short answer to it is that we are currently looking at it very hard. As I think we had adequate staff when we were proposing to stretch out the program to a 10-year program.

We're going to have to take a very careful look at that now that the program is being recompressed.

I would anticipate that we'll be going forward in the Department for a request for additional personnel for that if we do get in a bind. As you are aware, as we get into the negotiation of 50-60 projects and also the management of projects, we are going to hit a time of crunch.

So we're taking a very careful look at that.

Mr. **Walgren**. Then I guess, at first blush, looking at the overall budget for fossil R&D and particularly coal research, I guess I was hoping things would be a little different.

And it seems like that this is where we all came in with all these budgets in the last 10 years, with very major, major cuts.

Can you relate those cuts to the commitment that we have in the Clean Coal technology program? Do you see the Clean Coal technology program as compensating for the reductions in the actual R&D budget?

Mr. **Wampler**. No, I would have to say that I don't think it does compensate for it. We tried very hard to keep the Clean Coal Technology Demonstration Program separate from the R&D program because they have definitely two different purposes, even though some of the areas are complementary.

I think that what you see coming out of the R&D pipeline now are going to be further refinements to new technologies that are going to be important in 2000 and beyond.

So I think you have to keep them separate. Now, the one thing that the Clean Coal Technology Program has done for us, however, it's allowed us to cut short in some cases some proof of concept kinds of projects that we would be doing and go ahead and get them into the commercial form to be further tested at the Clean Coal Technology site.

I would imagine we'll see more of that at the tail end of the R&D cycle, as we go forward.

But, as far as keeping the programs separate, I think we must continue to do that because, again, the purposes are very different.

Mr. **Walgren**. But, then, if you look at the cuts in the coal research, the heaviest cuts, as I understand it, come in MHD and heat-engine, in fuel cells and coal liquefaction.

How was it that those cuts hit there? And how do we—is that a signal that these areas, whatever the investment has been made in the past, are now either finished or are to be disbanded.

As I understand it, the Congress has always supported a pretty broad-based effort in those areas because of a lot of things that were being learned. But here we are turning away from that.

What are the implications? Is that just wasted effort on our part at this point? Or do we have specific things that we point to that say that's what we were after and now we're walking away from it?

Mr. **Wampler**. I think we have—I think there are two issues. One is that, in cases, we have gotten the research to the point that we feel it's ready to be taken over by the private sector. In the case of phosphoric acid fuel cells, for example, there have been commercial offerings. There have been units sold.

So we think now it's proper for the private sector to continue that development.

If you look at the liquefaction line item, that's very misleading, because we're spending a lot of money for liquids from coal. The liquefaction line item results from the proposed stopping of the program at Wilsonville and LaPorte. Now, both of those programs have achieved some—in our opinion, have achieved their objective.

As I mentioned earlier, Wilsonville, we got the liquid price down now to the point of $30–35 a barrel. We don't think by going into that facility and, as I recall, the operating cost of that facility is about $8 million a year, and spending that kind of money, we don't feel that we can get the price down that much more substantially to justify that kind of money going into that facility.

So it's a combination of overall fiscal constraint and the fact that some of the programs are phasing down.

The case of MHD is different. We have absolutely no technical argument with MHD. It's good technology. The government spent around, as I recall, $600 million in the technology. It would take another $114 million, roughly, to develop it through its proof of concept.

And that's simply an issue of affordability. We have no technical quarrel with that technology.

Mr. **Walgren**. If we've put $600 million in it and it takes 114 more to finish it, what are the prospects of it being finished?

Mr. **Wampler**. Well, I think that the one thing that we're trying to look at—I know we've certainly been in an argument with Congress over, lo, these many years, on MHD.

We tried to work with community just very recently, the MHD community, to look at perhaps a fresh approach. We are looking at possible, some possible cooperative investment in this technology with countries like Italy, for example; possibly, Japan.

If we can come up with some innovative funding sources to get this technology to the point that it's ready to play in the Clean Coal Technology Program, I think that would be our ultimate answer.

But, again, it's a matter of affordability. It's an incredibly large ticket item for us.

Mr. **Walgren**. I know the Committee would be interested in a status report on advances in solid oxide fuel cells development. You mentioned the marketing of some fuel cells.

What's to be—what's the Department's view of that particular effort?

Mr. **Wampler**. I can talk a little bit about the Westinghouse program specifically. They have very recently developed or fabricated some cells which exhibit a great deal of superior single cell performance. We've accumulated somewhat over 4,000 hours in a stable test with that cell without any degradation at all.

They have had problems of their tubular cell that they had the degradation problems, but they seem with the defabrication to have overcome that.

In looking at those fuel cells generally, if we continue to make the significant progress that we feel we're making, we think that somewhere by the mid-nineties, the government will be out of that program and those will be on the market, just as phosphoric acid penetrated the market.

So, progress is being made.

Mr. **Walgren**. Well, I appreciate your responses, as we all do, and want to say that I appreciate the way that you personally have been supportive of things that made sense in fossil R&D. And we certainly hope that we can bring this area to some real vibrant advances.

Certainly, the Clean Coal technology program adds a lot and, yet, the ongoing research and development it would seem to me is critical as well. And I would hate to see that really diminished because we're making a specific effort in another area.

Thank you very much, Madam Chairman.

Mrs. **Lloyd**. Thank you very much, Mr. Walgren.

Allen, I don't want to be redundant, but I'd like to follow up on Mr. Walgren's comments on MHD and fuel cells in particular.

Now, it's my understanding that the Administration feels that they should no longer put any money into these programs and, yet, the private sector says:

Now, wait a minute. We can't finish this program by itself, only the program.

Now, are these programs too expensive to justify? Are we going to walk away at this point? Or, are we going to continue to make a commitment to them if we allow the funding?

Mr. **Wampler**. Well, I think the fuel cells——

Mrs. **Lloyd**. What I'm really trying to say is you are telling us that the private sector can take over at this point. The private sector said:

No, we can't.

Mr. **Wampler**. Well, I think we have to separate MHD and fuel cells. And we have to separate, in fuel cells, out of the phosphoric acid fuel cell, in particular.

That one has been offered for commercial sale in some quantity. It has been ordered in some quantity.

Mrs. **Lloyd**. But you understand that we're getting mixed signals.

Mr. **Wampler**. Yes, sure, I do understand that.

We feel definitely in the case of phosphoric acid fuel cell that, since it has been offered commercially, even though one contractor is working on a different type of process that won't be ready for several years, if we're looking at a problem in funding, that that certainly should be a factor when we decide to cut a program out.

The case of MHD is more problematic. As you know, under the five-year plan, the provision for cost-sharing for the private sector in MHD, if the government support was pulled on MHD, unless we can come up with an innovative method to fund, then I think the technology development would probably stop.

I think $114 million, it's not at the point that the private sector would come in and make that kind of investment to pick it up. To be honest, I would doubt that.

So that's a different problem. The large price tag to that program has been our problem.

Mrs. **Lloyd**. Do you feel in the case of MHD, do we continue to need this technology?

Mr. **Wampler**. I think MHD—I've never been able to make a technical argument against MHD. I think it's a good technology; if you look at it from the standpoint of what it does with CO_2, for example, it's one of the best.

So I simply cannot make a technical argument against MHD. I can make a budgetary argument against it, but not technical.

Mrs. **Lloyd**. You've been an excellent witness. We will be submitting some questions in writing for the record for you to respond to.

But there is one question I would like to ask before you leave us.

What technological barriers still exist to tapping our gas reserves? I don't think we've touched on that this morning.

Mr. **Wampler**. Well, I think that if you look at the barriers that do exist, I think we need a better understanding of drilling technology. I think we need a better understanding of the resources, a refined understanding of the resource itself.

I think we've got problems other than technical barriers. I think we need to take a look at the transportation system in this country for gas.

I think we also need before we ultimately realize the true value of gas, we need to take a hard look at ways that we can improve the price for methanol and those kinds of liquid products coming from gas, because gas is going to become a very valuable resource in this country.

So that generally is it.

Mrs. **Lloyd**. I see transportation then is the factor that ups the price of gas?

Mr. **Wampler**. Transportation is a factor, yes. It's not by any means we see an insurmountable problem. It's a matter of people are beginning to realize that——

Mrs. **Lloyd**. Well, I know it's not an insurmountable problem, but it factors into the cost.

Mr. **Wampler**. Yes, it does.

Mrs. **Lloyd**. To a larger degree than some of the other considerations.

Thank you very much. Thank you for being with us today.

[Status Report on Technology Progress follows:]

Committee:	House Committee on Science, Space and Technology
Subcommittee:	Subcommittee on Energy Research and Development
Date:	February 22, 1989
Witness:	J. Allen Wampler

INSERT FOR THE RECORD

STATUS REPORT ON TECHNOLOGY PROGRESS

A status report on technology progress to date in the demonstration phase of Round One is as follows:

- TIDD PFBC Demonstration Plant -AEP
  - Design work is 60% complete.
  - Construction is about 35% complete.
  - Pressure vessel has been fabricated and pressure tested, internals are being installed, and shipment is scheduled for May of 1989.

- Advanced Cyclone Combustor Demonstration - Coal Tech
  - Unit has been operated for some 350 hours under a variety of conditions.
  - Four coals have been tested.
  - NO_x reduction targets have been met.
  - Present operations are focused on SO_2 reduction and longer duration runs.

- Gas Reburning/Sorbent Injection - EER
  - Baseline testing has been completed at all three test sites in Illinois.

  - Engineering is 95% complete on the Edwards wall-fired boiler; 75% complete on the Hennepin tangentially-fired boiler; and 50% complete on the Lakeside cyclone boiler.

- LIMB Demonstration Project Extension - B&W
  - EPA plans to complete baseline testing of the LIMB technology by the end of May 1989.
  - DOE will complete installation of the Coolside duct injection technology in June 1989. Tests will begin in July and run through October 1989.
  - Following the Coolside test, further LIMB tests will be conducted by DOE using different coals and sorbents over longer periods of time than the EPA tests.

- The Appalachian Project - M.W. Kellogg
  - Proceeding with preliminary design to firm-up costs and develop NEPA inputs.
  - Kellogg is exploring a site change and arranging financing for Phases II & III.

- Circulating Fluidized Bed - Colorado-Ute
  - Project involves Phase III operations only.
  - Test plan has been negotiated.
  - Operation awaits acceptance of plant by Colorado-Ute of the 110MW Pyropower atmospheric circulating fluidized bed unit -- acceptance is expected imminently.

- Prototype Coal-Petroleum Co-Processing Plant
  - Preliminary engineering and cost estimates have been completed.

  - The process development unit is being operated to obtain needed design input.
  - Alternate sites are being explored.

- Underground Coal Gasification - Energy International
  - The site has been selected and characterized.
  - Preliminary design has been completed.
  - Detailed design on construction has been completed and initiated on equipment.
  - NEPA documentation has been completed.
  - Permitting for construction is in place.
  - Phase II & Phase III financing is being sought.

- Advanced Slagging Coal Combustor Utility Demonstration - TRW
  - Preliminary design on adapting combustors to the host site boiler is being studied.
  - Two coals are being tested on pilot scale unit to obtain needed design data.

Mrs. LLOYD. Our next witness is Dr. James Markowsky. He's representing the National Coal Association, and he will give us the private sector perspective of the Clean Coal Technology Demonstration Program.

Good morning, Dr. Markowsky.

Dr. MARKOWSKY. Good morning, Madam Chairman.

Mrs. LLOYD. Please proceed.

PANEL: CLEAN COAL TECHNOLOGY

STATEMENT OF DR. JAMES J. MARKOWSKY, SENIOR VICE PRESIDENT AND CHIEF ENGINEER, AMERICAN ELECTRIC POWER SERVICES CORP., ON BEHALF OF THE NATIONAL COAL ASSOCIATION

Dr. MARKOWSKY. Madam Chairman, I'm Jim Markowsky, Senior Vice President and Chief Engineer for American Electric Power Services Corporation.

American Electric Power Services Corporation is part of the American Electric Power System, which is comprised of eight operating companies in seven States—Michigan, Indiana, Ohio, West Virginia, Virginia, Tennessee and Kentucky.

The system is basically coal-fired; 85 percent of our capacity is coal-based. And that capacity is about 23,000 megawatts.

I'm pleased to be here today as a representative of the National Coal Association. Both the National Coal Association and American Electric Power are members of the Clean Coal Technology Coalition, which was organized in the spring of 1985 for the specific purpose of encouraging and implementing the Clean Coal Technology Program and accelerating development of problems in technologies.

I'd like to just divert from my written testimony and submit for the record a brief description of two Clean Coal technology programs that American Electric Power is pursuing under cost-sharing with the U.S. Department of Energy.

They are our KID 70-megawatt demonstration program which was selected and is well under-way now in the Clean Coal II, and our SPORN 330-megawatt repowering program, which was selected under Clean Coal II and we're currently right now in the negotiation phase.

Both those programs are pressurized fluidized beds.

And I'd like to submit that for the record.

Mrs. LLOYD. Without objection, it will be a part of the record.

[The information follows:]

PRESSURIZED FLUIDIZED BED COMBUSTION NEWSBRIEF

Pressurized fluidized bed combustion (PFBC) is an electric generating technology that is being developed to burn high sulfur coal effectively, meet stringent environmental standards, and produce electricity at a lower cost.

The advantages over present conventional coal-fired power plants with scrubbers include:

- *economic sulfur dioxide control*
- *less than half the nitrogen oxide emissions*
- *fewer solid waste problems*
- *higher generating efficiency*
- *reduced fuel consumption*
- *fuel flexibility*
- *lower capital costs*
- *modular construction*
- *flexible system planning*
- *lower cost of electricity*

Unlike present scrubber technology, PFBC removes sulfur during combustion of the coal — not after. PFBC can utilize a wider range of coal types — low-grade fuels, as well as high-sulfur coals, which may lead to operating problems in conventional plants, can be used effectively in the PFBC process.

Sulfur dioxide removal of 90% has been demonstrated by over 6000 hours of operation at the PFBC Component Test Facility in Sweden. These results supplement and confirm the over 2000 hours of testing at Great Britain's Coal Utilization Research Laboratory.

It has been further demonstated that PFBC produces less than half the nitrogen oxide of a conventional generating unit. This is also half the limit imposed by the U.S. Environmental Protection Agency.

PFBC represents a lower cost, more efficient generating system. Steam produced during the combustion process is used to drive a steam turbine. Hot gases resulting from the combustion process are cleaned and used to drive a gas turbine. Each turbine drives an electric generator. This combined-cycle approach results in a 10% increase in generating efficiency. Because less coal is required to produce the same kilowatt-hour, fuel costs are reduced.

Because of pressurized operation and better heat transfer characteristics, PFBC components and plant facilities are considerably smaller than conventional units of equal generating capacity. This results in significant cost savings in equipment and structural steel, shorter plant construction periods, and reduced land requirements.

Pressurized fluidized bed combustion uniquely joins two previously unrelated power generating systems: the fluidized bed and the combination gas turbine and steam turbine electric generation cycle. See Figure 1.

The fluidized bed is basically a container (combustor) in which the combustion process occurs. Because of its pressurized operation, the combustor is considerably smaller than a conventional boiler of equal thermal capacity.

The process begins when a mixture of crushed coal and dolomite (a form of limestone common in the Midwest) is injected, along with a uniform flow of air through the bottom portion of the combustor.

When the air velocity inside the combustor reaches a certain level, the solid particles of coal and dolomite assume a random-type motion and appear to float or "fluidize." The fluidized motion ensures thorough mixing of the suspended particles.

During this process the coal is burned and the dolomite absorbs the sulfur oxides that are produced. Combustion temperature is approximately 1600°F, or about half that encountered in a conventional boiler.

The sulfur-laden dolomite forms dry, solid waste product. Some of this waste product, in the form of bed ash, is removed through the bottom of the combustor. Smaller ash particles, or fly ash, are carried from the top of the bed by hot gases produced during the combustion process.

The gases pass through dust collectors where the fly ash is removed. This separation procedure minimizes the potential of erosion and corrosion damage to the gas turbine. The combustion gases then turn the gas turbine. This gas turbine drives both an air compressor (which provides combustion air for the fluidized bed) and a generator to produce electric power.

Gases exhausting from the gas turbine are used again — this time to preheat feedwater for the steam turbine cycle. The preheated feedwater is then sent through the tubes submerged in the fluidized bed boiler.

The tubes extract heat from the combustion process in the boiler and convert the feedwater to steam. The steam is used to turn a steam turbine generator that produces the bulk of the plant's electric power.

American Electric Power's (AEP) Tidd Demonstration Facility is an important step toward the commercialization of PFBC technology in the United States. As a predecessor to the first full-scale commercial unit, Tidd will be operated as a smaller-scale PFBC combined-cycle demonstration plant. AEP received a $60.2 million grant to finance the $167.5 million project under Phase I of the federal Innovative Clean Coal Technology Program. This grant is being administered by the U.S. Department of Energy's (DOE) Morgantown Energy Technology Center. In addition, the Ohio Coal Development Office has awarded $10 million under Ohio's $100 million clean coal program.

(Combustion Newsbrief continued)

Construction is continuing at a very high pace in support of AEP's 70,000 kilowatt Tidd PFBC Demonstration Plant in Brilliant, Ohio. The Tidd Plant site has taken on an entirely new look since construction work began in April, 1988. Earth moving and foundation work is nearing completion, and steel erection began in November for the combustor building which will house most of the new PFBC components. Fabrication of the combustor pressure vessel was completed and the vessel was pressure tested in November. Following installation of the internal components, the combustor will be shipped to Tidd in May, 1989. The plant is expected to begin three years of test operation in 1990. AEP expects to obtain a great deal of technical information from the three year test program. This information will be invaluable as the company proceeds with design plans for the nation's first commercial PFBC facility — the Sporn Repowering Project.

In September, 1988, the U.S. Department of Energy selected AEP to receive a $185 million grant to help finance the $579 million Sporn Project. The grant was awarded under Phase II of the federal Innovative Clean Coal Technology Program.

Negotiations toward a cooperative agreement are underway between AEP and DOE. The repowering project calls for the replacement of the plant's two 1950-vintage, 150,000 kilowatt boilers with a 330,000 kilowatt PFBC combustor, a 10% gain in output. The Philip Sporn Plant on the Ohio River near New Haven, West Virginia, was selected for repowering because of its age, size and proximity to abundant coal fields.

Engineering and design work is expected to begin in late 1989 and plant construction in early 1993. Operation could begin in late 1995.

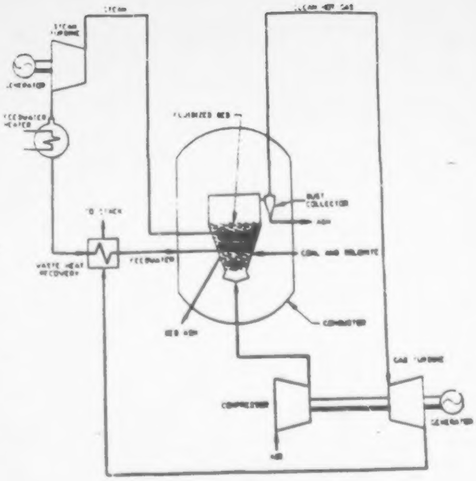


FIGURE 1 PFBC COMBINED CYCLE

DOE NAMES THREE REPLACEMENT PROJECTS FOR ROUND I

The Department of Energy (DOE) annnounced that it has selected three replacement projects to receive funding under Round I of the DOE clean coal program. Approximately $25-30 million in federal funds became available when DOE and the Minnesota Department of Natural Resources were unable to complete negotiations on the Minnesota project that was selected for funding under the first, $400 million DOE solicitation. Proposals by Combustion Engineering, United Coal Company and Western Energy, which were chosen as alternates under Round I, will be the recipients of the funds. Combustion Engineering proposes to demonstrate advanced combustion of medium and deep cleaned coal; United Coal Company proposes to demonstrate microbubble flotation and centrifugal drying of coal preparation wastes; and Western Energy proposes to demonstrate coal preparation by advanced cleaning and processing of sub-bituminious and lignite coal. If you would like more information on these three replacement projects, please contact *Sherri Crawford* at (202) 298-1893.

COALITION WELCOMES NEW MEMBERS:

The Clean Coal Technology Coalition has added six new members since the publication of the last Coalition newsletter in October. The Coalition is pleased to welcome the following:

Montana State University
Passamaquoddy Technology
Public Service Company of Colorado
Roberts and Schaefer Company
The University of Montana
Western Research Institute

NEW COALITION TELEPHONE NUMBER

The Clean Coal Technology Coalition has a new telephone number: (202) 342-3368. The phone will be answered weekdays from 8:00 a.m. through 6:00 p.m. Please make a note of our new phone number.

Dr. **Markowsky.** Coal is our nation's most abundant fossil fuel. Coal is the central fuel base the utility industry will rely upon on meeting both current and future demands for electric power.

The wide range of technologies now being developed under the Clean Coal technology program—that's Round One and Two, and those anticipated in Round Three, Four and Five offer significant potential to facilitate the use of coal and other fossil fuels in a more environmentally-acceptable manner while simultaneously increasing both fuel efficiency and cost-effectiveness.

Further, it is worth emphasizing the concern about the reliability of future electric power generating capacity as the demand for electricity grows at a faster rate than expected.

Decisions regarding capacity to meet new demand and capacity to replace generation that has basically ended its useful life are beginning to be made.

The rate at which these decisions will be made will accelerate throughout the 1990s; therefore, it is important that these new, more efficient technologies be commercialized on an expeditious basis as proven options for both utilities and industry to consider when making those decisions.

The Clean Coal technology program must be an integral part of our nation's energy policy, which strives to balance the goals of energy security, economic growth and a need to protect our environment.

It is vital that this program be continued. The coal industry appreciates the strong support that you and the other members of the Subcommittee have given the Clean Coal program. This support has enabled this strategic program to move forward.

Restoration of the original, innovative Clean Coal technology funding level sends an important signal to domestic energy-producing and consuming industries that the Administration is serious about energy and the environment, and is concerned about the potential shortfalls in energy supplies and wants to meet the future energy requirements by relying on domestic, not imported fuel supplies.

Finally, a revised schedule of fulfilling funding of the—basically, it will coincide with the 1987 U.S. commitment to the Canadians to devote $2.5 billion over a five-year period for demonstration of innovative control technologies.

Adequate and reasonably-priced energy supplies are imperative to sustain long-term economic growth. In early 1989, both the Department of Energy and the Edison Electrical Institute released reports with forecasts that demand for electricity will increase at an average annual rate of 2.4 percent between 1988 and the year 2000.

This is approximately a 20 percent higher forecast than just a year ago.

These demands cannot be met by the current and planned capacity generation addition.

Corresponding to this problem is the fact that between the years 2000 and 2010, approximately 25 percent of the existing capacity will be 50 years or older. This capacity must also be replaced or repowered with new capacity.

It is clear that new cost-effective and environmentally-clean generating capacity will be required to both meet new demands and as replacement capacity.

This underscores the urgency for innovative Clean Coal technology deployment and commercialization and a need to keep the program on schedule.

U.S. coal is the most logical means to meet new demand for electricity. Resource availability, security of supply, stable fuel prices and lower long-term costs all suggest that coal-based capacity will be the long-term choice of utilities when considering new generation options.

However, there is a concern that an increase in coal consumption will lead to an increase in SO_2 and NO_x emissions. Both private industry and government studies have found that SO_2 emissions are trending downward. Existing conventional technologies, such as coal cleaning, conventional scrubbers, are viable options that allow utilities to meet this cost-performance standard.

However, coal utilization will not reach its full potential absent new, more cost and fuel efficient technologies now being developed under the Clean Coal technology program.

These technologies are the keys to the compatibility of cost-effective generation and concurrent emission reductions.

The Clean Coal technology program is truly national in scope. The coal industry supports the effort of the Department of Energy to encourage as broad a participation as possible in this program.

It is important that a complete menu of technologies be commercially available to all utilities and industrial users on a timely basis. Further, industry supports DOE's efforts to extend these technologies to foreign markets, which will enhance the marketability of U.S. coals abroad.

A significant period of time will be required for innovative Clean Coal technologies to be demonstrated, deployed and utilized. This is because there are substantial risks associated with any new technology, a particularly acute problem in the electric utility industry.

Electric utilities must give priorities to least cost options when considering new generation options. Utilities are also required that the option chosen guarantee a high level of plant availability and reliability.

Other disincentives to utility investing include prudency reviews by regulatory commissions, which have made utilities reluctant to invest in anything other than conventional, tried and proven technologies.

These disincentives tend to discourage utility investment in new and unproven technologies. Without federal cost and risk-sharing, innovative Clean Coal Technologies will be hampered and with that cost they should be developed on a timely basis.

It is important to support a multi-year deployment program that allows cost-sharing of multiple plant applications of a particular technology to accelerate the commercialization of these technologies and assure that the projected availability dates in my written statement are attained.

It is well-accepted that the first commercial project using a particular technology will be more costly than subsequent applications. The objective of the multi-plant program is to refine the technology so the capital and operating costs that are subsequently privately-funded and associated investment risks can be minimized.

It is important that the Department of Energy now evaluate steps to facilitate deployment and subsequent, broad-based commercial acceptance of these technologies that are being developed under the innovative thing called Technology Programs.

Two recent reports, one from the National Coal Council and the other from the Innovative Control Technology Advisory Panel, on the deployment of Clean Coal technologies offer sound advice in that direction.

These reports, which focused on new, incentive-based policies which emphasize economic efficiency and environmental protection, address the technical, commercial, environmental, regulatory constraints to the private sector in developing and utilizing these technologies.

The reports both recognize the possibility that the promise of the program could be compromised by legislation or regulation mandating additional emission reductions required beyond existing law.

The magnitude and timing of these additional emission reduction requirements could severely restrict the opportunity and incentives for innovative Clean Coal technology deployment and subsequent commercial use.

As noted in the National Coal Council's Report, and I quote:

"The demonstration and deployment of innovative Clean Coal technology will take time. Even after this technology becomes available for confident commercial use, an additional five to 10 years or more, depending on the complexity of the technology and the scope of the market, may be required before it reaches its first full commercial potential.

"This time frame must be recognized in establishing regulatory compliance schedules if innovative Clean Coal technology deployment is to proceed effectively."

Within the context of the National Coal Council report, a number of recommendations are made which I have summarized in my written statement.

The National Coal Council report in conjunction with the report and recommendations of the innovative control technologies advisory panel for the Secretary sets both the framework and the elements of an action plan to achieve improvements in the environment for the use of new and innovative Clean Coal technology.

Coal is an appropriate technology. It is clean and economic energy. The innovative Clean Coal technology program has laid the foundation for a more cost-effective and fuel efficient use of coal.

Our nation must use coal to assure the continued availability of least cost electric power for homes, businesses and industries.

While progress has been made to the innovative Clean Coal program, additional policy actions are necessary to facilitate more rapid deployment of these technologies.

We urge the Subcommittee to support President Bush's fiscal 1990 budget request for appropriations to complete the program.

Thank you very much. And I'll take any questions.

[The prepared statement of Dr. Markowsky follows:]

NATIONAL COAL ASSOCIATION

STATEMENT OF

DR. JAMES J. MARKOWSKY
SR. VICE PRESIDENT AND CHIEF ENGINEER
AMERICAN ELECTRIC POWER SERVICES CORPORATION

ON BEHALF OF
THE NATIONAL COAL ASSOCIATION

before the
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON SCIENCE AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES

February 22, 1989

HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

HEARINGS ON FISCAL YEAR 1990 BUDGET REQUEST
DEPARTMENT OF ENERGY -FOSSIL ENERGY PROGRAM
FEBRUARY 22, 1989

STATEMENT OF THE NATIONAL COAL ASSOCIATION

Madame Chairman, I am Dr. James J. Markowsky, Sr. Vice President and Chief Engineer, American Electric Power Services Corporation[1]. I am pleased to be here today as a representative of the National Coal Association (NCA). The American Electric Power Company (AEP) mines approximately 14 million tons of coal per year and, in 1988 had a coal burn of approximately 42 million tons. AEP is a member of the National Coal Association and is represented on its Board of Directors. NCA is an organization representing producers of coal from the smallest to the largest, operating in all producing regions of the country and mining all qualities of coal. NCA member operations comprise the majority of the coal production in the United States.

Both NCA and AEP are also members of the Clean Coal Technology Coalition which was organized in the spring of 1985 for the specific purpose of encouraging the implementation of the clean coal program and the accelerated development of promising technologies.

Coal is our nation's most abundant fossil fuel. Coal is the central fuel base the utility industry relies upon to meet both current and future demands for electric power. The wide range of technologies now being developed under the Clean Coal Technology program (Rounds One and Two), and those anticipated in rounds three, four and five, offer significant potential to facilitate the use of coal and other fossil fuels in a more environmentally acceptable manner while simultaneously increasing both fuel efficiency and cost effectiveness.

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[1] Dr. Markowsky is Sr. Vice President and Chief Engineer, American Electric Power Services Corporation. He has had eighteen years experience in engineering and design of both fossil and nuclear generating stations for the AEP. In addition, during the past twelve years, he has had experience in evaluating new-energy technologies including: In-Duct Scrubbing, LIMB, Advance Coal Cleaning, Integrated Coal Gasification Combined Cycle, Atmospheric Fluidized Bed Combustion, and Pressurized Fluidized Bed Combustion. Dr. Markowsky received a BME from Pratt Institute, an MS and PhD in Thermal Engineering from Cornell University and MBA from MIT.

Further, it is worth emphasizing concerns about the reliability of future electric power generating capacity as demand for electricity grows at a faster rate than expected earlier in this decade. Decisions regarding capacity to meet new demand and capacity to replace generating capacity that is ending the period of useful life are beginning to be made. The rate at which these decisions must be made will be accelerated throughout the 1990's. Therefore it is important that these new technologies be commercially available on an expedited basis as a proven option for both utilities and industry to consider when making those decisions.

The Clean Coal Technology program must be an integral part of our nation's energy policy which strives to balance the goals of energy security, economic growth and the need to protect our environment. It is vital that this program be continued.

The coal industry appreciates the strong support that you and other members of this subcommittee have given the clean coal program. This support has enabled this strategic program to move forward.

The coal industry was concerned about the initial "program stretch out" and the potential delay in development and deployment of Innovative Clean Coal Technologies (ICCT). A delay of even two years in continuation of project funding would most certainly discourage many private developers from participation in the program due to the questions such a postponement would raise about continued availability of federal funding.

We strongly support the appropriation levels included in President Bush's revised budget plan which carry forward the original Clean Coal Technology program funding levels and schedule. The revised budget proposals will assure the private sector of a continuing federal commitment to the accelerated demonstration and initial deployment of the technologies to the point of commercial availability.

Restoration of original ICCT funding levels sends an important signal to domestic energy producing and consuming industries that the Administration is serious about energy and the environment, is concerned about the potential shortfall in energy supplies and wants to meet future energy requirements by relying on domestic, not imported, fuel supplies. Keeping the ICCT program on its original track is equally important to many in the international community that look to the United States to play a leadership role in

balancing the need for energy and energy security with environmental protection goals. Finally, the revised schedule of funding fulfills the 1987 U.S. commitment to the Canadians to devote $2.5 billion over a five year period for demonstration of innovative control technologies.

Adequate and reasonably priced energy supplies are imperative to sustain long term economic growth. However, the United States is vulnerable on two fronts: through an increase in dependence on imported energy and from pending shortages in electrical generating capacity. Expanding the capability to use coal in greater quantities can simultaneously address both.

The Department of Energy forecasts show that consumption of energy in the United States is expected to increase at a 1.1 percent annual rate during the remainder of this century to total 90.6 quads (quadrillion Btu) in 2000.[2] This is a 13 percent increase in energy consumption over the 1988 level of 79.4 quads and is more than double the average 0.56 percent annual rate of increase experienced over the last 12 years.

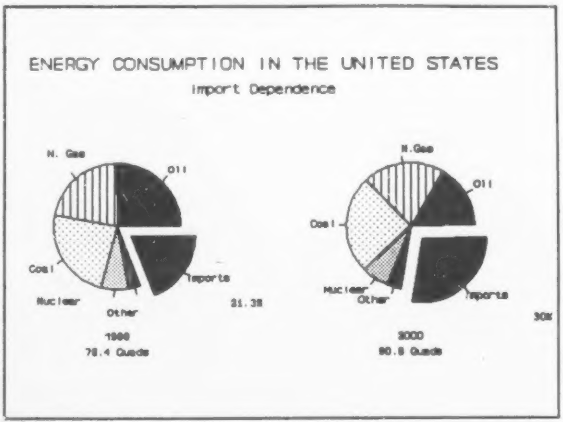

Figure 1

The projected increase in energy consumption is accompanied by an unwelcome projection of an increase in the United States dependence on imported energy (petroleum, electricity, natural gas). The use of imported energy, which supplied 21.3 percent of U.S. energy use in 1988, is expected to grow at a very rapid annual rate of 4.0 percent between now and the end of the century. As illustrated in Figure 1, imported energy will provide almost 30 percent of the total energy used in the United States in

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[2] 1989 Annual Energy Outlook, Long Term Projections, Energy Information Administration, Department of Energy, January, 1989. Base case estimates are cited throughout this statement.

2000. Net petroleum imports, the barometer most closely watched, are expected to increase from an average 6.3 million barrels per day (13.6 quads) to 10.2 MMbbls/day (22 quads) by 2000. This would account for 55 percent of all petroleum used in the U.S. in 2000 and 24.3 percent of total energy used in that year.

It is clear that there must be an increase in production and use of all forms of domestic energy to reverse the trend towards import dependence. It is equally clear that each domestic energy source has a unique role to play in reversing this trend. For example, the use of natural gas based fuels in the transportation, residential and light industrial sectors can offset the use of imported oil.

Until technologies that permit the substitution of coal based fuels for petroleum in the transportation sector are more fully developed and commercialized, coal is most logically used in the utility and heavy industrial sectors for the generation of electricity and process steam. Since the oil price shocks of the 1970's, non-petroleum based electricity has replaced other energy forms to reduce reliance on oil. This has resulted in a sharp increase in dependence on electricity to meet end use energy requirements. To illustrate, in 1976, electricity met 29 percent of end use energy consumption needs. In 1988 this figure was 36 percent and by 2000, DOE projections show that 42 percent of end use energy requirements will be met with electricity.[3] Coal's contribution to power generation has increased over the 1976 - 1988 time period. In 1976, coal generated 46 percent of electricity, in 1988 coal generated 57 percent. Coal has been use to replace imported oil and to meet new demands for electricity.

In early 1989 both the Department of Energy and the Edison Electric Institute released reports with forecasts that demand for electricity will increase at an average annual rate of 2.4 percent between 1988 and 2000.[4] These demands cannot be met with current and planned generating capacity. According to an earlier DOE analysis that was based on 1988 projections by the National Electric Reliability Council, "If demand grows at the rate utilities project (i.e., NERC's 1.87 percent per year, 1988 - 1997) and utilities obtain the demand management and third party supply they are planning for, the supply of electricity will be adequate. If demand grows at a faster rate or third party supply and demand management does not materialize at the rate anticipated, utilities will need new supply sources."[5] The new DOE and the EEI forecasts, as well as the experience over the last two years (in 1987, electricity demand increased by 3.4 percent and in 1988, by 5.0 percent) suggest that utility planning based on a 1.87 percent annual growth rate will result in electricity generating capacity shortfalls. Compounding this problem is the fact that by 2000, 25 percent of existing capacity will be 50 years or older. This capacity must also be replaced with new capacity or repowered.

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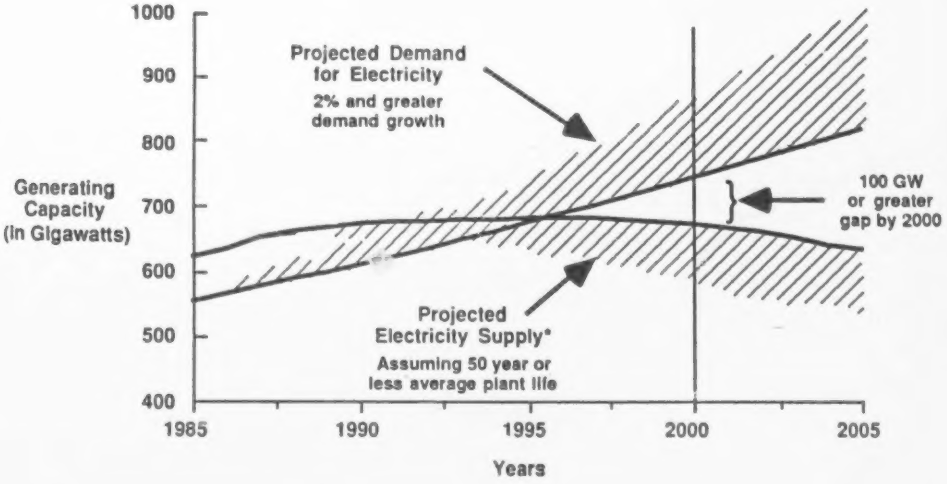
[3] This estimate represents only the electricity produced and/or distributed by electric utility companies. Therefore, the estimate of dependence on electricity understates the total due to power requirements met by industrial self-generation.

[4] DOE - 1989 Annual Energy Outlook; the Edison Electric Institute, Electricity Future: America's Economic Imperative.

Need for New Capacity Expected To Grow Rapidly After 1995



*Existing plants plus plants under construction minus retirements.

Source: Energy Security Report to the President, DOE, 1987

It is clear that new, cost effective and environmentally clean generating capacity will be required both to meet new demands and as replacement capacity. This underscores the urgency for ICCT deployment and commercialization and the need to keep the program on schedule.

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[5] Electric Supplies for the 1990's: Growing Reliance on Demand Management and Third Party Suppliers, U.S. Department of Energy, Office of Policy, Planning and Analysis, October, 1988

Energy security concerns effectively preclude an increase in the use of petroleum. Long term supply concerns and long term cost considerations preclude a sharp increase in the use of natural gas for base load electricity demand The nuclear option may be precluded in the near term. Load management and conservation need to be aggressively pursued as a part of the energy mix. Utilization efficiency gains through conservation however, can only partially offset the projected increase in demand for electric power. In fact, the most significant gains to be achieved in the use of energy are in the transportation sector where, in part, electricity will be relied upon to replace traditional transportation fuels.

U.S. coal is the most logical means to meet new demand for electricity. Resource availability, security of supply, stable fuel prices and lower long term costs all suggest that coal based capacity will be the long term choice of utilities when considering new generating options.

Coal reserves are sufficient to meet any increased level of demand over the long term at stable prices. Conversely, as the recently released DOE report, Electricity Generation from Natural Gas: Prospects and Implications for the United States [6] concluded, "If utilities should choose to consume gas at the same or higher levels that those projected in 2000, it appears that the assumed volume of economically recoverable resources would not be adequate to meet requirements at competitive prices."

The study projected that natural gas wellhead prices (base case, 1988 dollars per thousand cubic feet) would increase from $1.68 in 1988 to $3.90 in 2000. Average prices of natural gas to utilities would increase from $2.29 to $4.26/MMbtu. According to DOE, the average price that utilities would pay for coal is forecast to increase from $1.52 to $1.68/MMbtu over the same time frame. These projections which are illustrated inFigure 3 on page 7, underscore the long term price stability of coal compared with natural gas. Higher projected prices for natural gas coupled with concerns over fuel availability over a forty year time frame bring into question the long term life cycle costs ofnatural gas when compared with coal.

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[6] Energy Information Administration, Department of Energy, January, 1989.

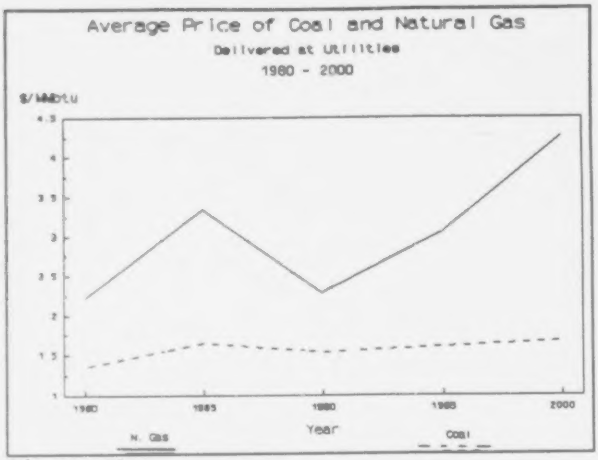

Figure 3

Despite these clear economic advantages, there is concern that an increase in coal consumption will lead to an increase in SO_2 and NO_x emissions. Both private industry and government studies have found that SO_2 emissions are trending downward. Existing conventional technologies - coal cleaning, conventional scrubbers - are viable options that allow utilities to meet current NSPS standards. However, coal utilization may not reach its full potential without the new, more cost and fuel efficient technologies now being developed under the Clean Coal Technology program. These technologies -- pre-combustion, combustion and post combustion -- are the key to the compatibility of cost-effective generation and concurrent emissions reduction.

Table One, "Environmental Performance of Innovative Clean Coal Technologies in Comparison to Conventional Coal Fired Power Plant," shows that a reduction of both SO_2 and NO_x is possible with most technologies that are now in the advanced demonstration stage. Commercialization and utilization of these technologies will result in a long term decline of SO_2 and NO_x emissions in the face of sharply rising coal use as illustrated in the analysis included in a recent National Coal Council Report and reproduced as Figure 4 on page 8.[7]

In the long term, utility emission control costs will be lower with ICCT. The NCC report states that by 2010 the potential savings as compared with current emission control practices, could be as much as $5 billion per year. These savings result from the integration and simplification of emissions control which in turn reduces operating costs relative to current technologies. Savings are found at both new and repowered plants using ICCT.

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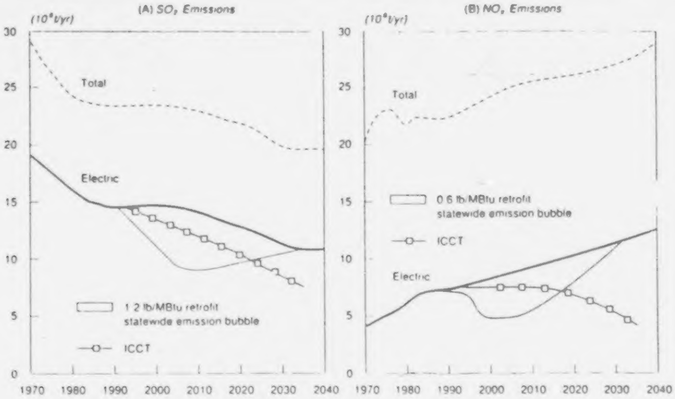
[7] Innovative Clean Coal Technology Deployment, The National Coal Council, November, 1988

FIGURE 4 ICCT Impact Upon Projected Annual SO_2 and NO_x Emissions



- Total: Total U.S. emissions trend
- Electric: Electric power emissions based on 2.1% per year demand growth, 20% reserve margin after 1996, 60GW of new gas fired capacity by 2000, no nuclear additions after 1996, 60 year fossil plant life, 40 year nuclear plant life, and no change in fuel sulfur content or control requirements (baseline)
- New ICCT Plants: Emission trend resulting if power plants utilize innovative clean coal technology. The rate of market penetration is strongly influenced by deployment incentives
- Bubble: Emission trend resulting from a statewide emission control bubble

SOURCE: NAPAP and Electric Power Research Institute

Finally, some technologies for repowering, for example pressurized fluidized bed combustion and integrated gasification combined cycle sharply improve the fuel conversion efficiency when compared to current technology. (See Table 2 attached.) Other technologies being developed promise to reduce the amount of power needed to operate emission control devices. Current wet scrubber technology requires up to 5 percent of the power plant's output. More advanced scrubbers and other control options would reduce the capital and operating costs of the plant and will slightly increase the fuel conversion efficiency of the power plants.

These advantages are not limited to any particular type of coal or to any particular geographic region of the country. Advantages of clean coal technologies apply to utilities in the East, in the West and to both the low and high sulfur coal producer and consumer. For example:

- Nitrogen oxide emissions are of growing concern throughout the nation. Many new technologies, like fluidized bed and IGCC, control NO_x emissions as well as SO_2 emissions during combustion/conversion.

- Since most of the increase in electricity demand is expected to occur in the West, lower cost facilities with multiple emission control capability can be especially important for that region.

- Current NSPS requirements necessitate sulfur reduction for all coals in new power plants. Lower cost sulfur removal technologies will enhance the marketability of all coals, especially those technologies in which operating costs are largely dependent upon the amount of sulfur to be removed.

- In the West, state-imposed new source standards and/or PSD limits often require emission levels below federal NSPS requirements. In such cases, even the lower sulfur coals must be subjected to sulfur removal technologies in order to meet these stringent limits.

- Certain clean coal technologies are specifically applicable to low-sulfur coal and will encourage low-sulfur coal use. These include: advanced physical coal cleaning, low rank coal beneficiation, sorbent injection and fluid bed combustion.

The Clean Coal Program is truly national in scope. The coal industry supports the effort of the Department of Energy to encourage as broad a participation in the program as possible. It is important that a complete menu of technologies be commercially available to all utilities and industrial users on a timely basis. Further, the industry supports DOE efforts to extend these technologies to foreign markets to enhance the marketability of U.S. coals abroad.

Significant periods of time will be required for Innovative Clean Coal Technologies to be demonstrated, deployed and utilized without programs designed to specifically assist in their accelerated development. This is because there are substantial risks associated with any new technology, a particularly acute problem in the electric utility industry. Utilities must give priority to the least cost approach when considering new generating options. Utilities also require that the option chosen guarantee a high level of plant reliability.

Other disincentives to utility investment, including prudence reviews by regulatory commissions, have made utilities reluctant to invest in other than conventional, proven technologies. These disincentives tend to discourage utility investments in new, unproven technologies, which may or may not meet projected performance and emission reduction levels. With federal cost and risk sharing however, ICCT should be developed on a timely basis as shown in Table 3 attached, "Range of Estimated Commercial Availability Dates of Clean Coal Technologies".

It is important to support a multi-year deployment program that allows cost sharing of multiple plant applications of a particular technology in order to accelerate the commercialization of these technologies and to assure that projected availability dates are attained. It is well accepted that the first commercial project using a new technology will be more costly than subsequent applications. The objective of a multi-plant program is to refine technology so that the capital and operating costs of subsequent privately funded plants and the associated investment risks can be minimized.

It is important that the Department of Energy now evaluate steps to facilitate deployment and, subsequently, broad based commercial acceptance of the technologies being developed under the Innovative Clean Coal Program. Two recent reports [8] on the deployment of Clean Coal technologies offer sound advice in that direction.

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[8] In December the National Coal Council issued its report titled Innovative Clean Coal Technologies Development and in January, 1989 the Innovative Control Technology Advisory Panel (ICTAP) of the Department of Energy issued a Report to the Secretary of Energy Concerning Commercialization Incentives.

These reports, which focused on new incentive-based policies emphasizing economic efficiency in environmental protection, addressed the technical, commercial, environmental, and regulatory constraints to private sector development and utilization.

The reports both recognize the possibility that the promise of the program could be compromised by legislation or regulation mandating additional emission reduction requirements beyond existing law. The magnitude and timing of these additional emission reduction requirements could severely restrict the opportunity and incentive for ICCT deployment and subsequent widespread commercial use. As noted in the National Coal Council report:

> "The demonstration and deployment of ICCT will take time. Even after a technology becomes available for confident commercial use, an additional five to 10 years or more -- depending on the complexity of the technology and the scope of the market -- may be required before it reaches its full commercial potential. This time frame must be recognized in establishing regulatory compliance schedules if ICCT deployment is to proceed effectively."

Within this context the National Coal Council report made a number of recommendations. Those relevant to domestic development of ICCT's were to:

1. Complete the ongoing DOE-cosponsored ICCT demonstration initiative as planned.
2. Clearly define the scope and extent of ICCT "Deployment."
3. Actively encourage, at the state level, utility and industrial participation in ICCT deployment efforts.
4. Ensure that air quality legislation places priority on sustaining the remarkable national progress made over the past 15 years in emission reduction with the least impact on cost and productivity.
5. Lower federal and state environmental regulatory barriers to wider use of ICCT options by providing flexible source emission reduction targets, which would include "bubbling" to reduce costs by allowing averaging of emissions over all facilities in a state or region provided that ambient air standards are maintained.

6. Modify federal, state, and local environmental permitting procedures to expedite and encourage ICCT deployment, and provide a permitting reference for consistent and uniform application of federal regulations.
7. Conduct an ICCT public education and consensus-building campaign.
8. Provide, where appropriate, federal and state economic incentives to accelerate ICCT deployment without distorting the energy market.

These recommendations, and others, are discussed in the report which was previously forwarded to the full committee. The NCC report, in conjunction with the report and recommendations of the ICTAP to the Secretary, sets both the framework and the elements of an action plan to achieve improvement in the environment through the use of new and innovative clean coal technologies.

Coal, with appropriate technology, is clean energy. The ICCT program has laid the foundation for more cost effective and fuel efficient clean use of coal. Our nation must use coal to assure the continued availability of least cost electric power for its homes, businesses, and industries. While progress has been made through the Innovative Clean Coal Program, additional policy actions are necessary to facilitate more rapid deployment of clean coal technologies. We urge the Subcommittee to support President Bush's FY 1990 budget request for appropriations to complete the program.

Thank you very much, I would be pleased to answer your questions.

TABLE ONE

Environmental Performance of Innovative Clean Coal Technologies in Comparison to Conventional Coal-Fired Power Plant

Technology	% SO_2 Reduction	NOx Emitted	Waste Charactersitics
CONVENTIONAL			
Coal Cleaning	10-30	No change	Solids disposal
Flue Gas Scrubber	90+	No change	Sludge
RETROFIT			
Advanced Flue Gas Cleanup	90+	High reduction	None, Byproduct produced
Limestone Injection Multistage Burner	50-60	Moderate reduction	Dry nontoxic powder suitable for landfill
Slagging Combustor	50-90	Moderate reduction	Dry non-toxic powder suitable for landfill
Gas Reburning	10-20	Moderate reduction	None produced
In-duct Sorbent Injection	50-70	No change	Dry powder suitable for landfill
Advanced Coal Cleaning	30-90	No change	Solids disposal
Coal Slurry	10-90	No change	Solids disposal
REPOWERING			
Integrated Gasification Combined Cycle	95-99	Moderate reduction	Usable slag, saleable sulfur and small quantities of other solid wastes
Pressurized Fluidized Bed Combustion	90-95	Moderate reduction	Dry granular nontoxic solid waste
Atmospheric Fluidized Bed Combustion	85-90	Moderate reduction	Dry granular nontoxic solid waste

Source: Department of Energy's report,
"America's Clean Coal Commitment,"
February 1987

TABLE TWO

TECHNICAL AND ECONOMIC PERFORMANCE OF CLEAN COAL TECHNOLOGIES

TECHNOLOGY	EFFICIENCY	POWER OUTPUT	PLANT LIFE	INCREMENTAL* COST OF ELECTRICITY (mills/kWh)	CAPITAL COSTS ($/kW)
CONVENTIONAL					
Coal Cleaning	Small Increase	No Change	Slight Extension	2-3	Fuel Only
Flue Gas Scrubber	Decrease	Moderate Decrease	No Change	9-11[1]	180-200
RETROFIT					
Advanced Flue Gas Cleanup	Decrease	Small Decrease	No Change	10-12	175-190
Limestone Injection Multistage Burner	Decrease	Small	No	5-8	80-110
Slagging Combustor	Small Decrease	Small Decrease	Slight Extension	1-2	50-60
Gas Reburning	No Change	No Change	Slight Extension	Depends on Gas Price	10-20
In-Duct Sorbent Injection	Small Decrease	Small Decrease	No Change	2-4	40-90
Advanced Coal Cleaning	Small Decrease	No Change	Slight Extension	6-21	Fuel Cost Only
Coal Slurry	Small Decrease	Small Decrease	No Change	11-23	20-50
REPOWERING					
Integrated Gasification Combined Cycle	Moderate Increase	50-150% Increase 10-30%	Moderate Extension	1-2[2]	1100-1300
Pressurized Fluidized Bed Combustion	Slight Increase	40-50%[3] Increase	Moderate Extension	4-6	800-1000
Atmospheric Bed Combustion	No Change	10-15% Increase	Moderate Extension	6-8	700-900

SOURCE: "America's Clean Coal Commitment:, U.S. Department of Energy Office of Fossil Energy, February 1987)

*Assumes base is conventional coal-fired power plant with only particulate removal devices. For repowering technologies, capital costs are relatively high to retrofit technologies because the output, i.e. capacity of the plant is considerably increased. The incremental cost of electricity are those costs associated with reducing emissions from the original plant.

[1] It is our opinion that Conventional Flue Gas Cleanup would have a higher incremental cost of electricity than Advanced Flue Gas Scrubber -- 12 to 14 Mills/kWh. However, if selective catalytic reduction (SCR) is included, Advanced Flue Gas Cleanup could have higher cost of electricity. It should then be reflected in capital cost also.

[2] The Incremental Cost of Electricity for IGCC as referenced in the DOE table is confusing. If Capital Cost of repowering is assumed to be $1000 to 1300/kW, the incremental capital charge alone would be much higher than 1 to 2 mills/kW-hr as predicted by US DOE and might be approximately 10 to 15 mills/kW-hr.

[3] Studies conducted by American Electric Power shows that PFBC Repowering will be capable of maximum net capacity increase by 30% and could be as low as 10%, rather than 40 to 50% stated in the table.

TABLE THREE

**Range of Estimated Commercial Availability
Dates of Clean Coal Technologies
(assumes implementation of a clean coal deployment program)**

Technology Class	Available for Commercial Order* (Range of Estimates)	Potential Widespread Commercial Use to Achieve Reductions of Air Pollutants**
Advanced Physical Coal Cleaning	1994-1996	Post 2000-2005
Chemical Coal Cleaning	1998-2000	Post 2010-2015
Low Grade Coal Upgrading	1993-1995	End 1990's-2000
Advanced & Regenerable FGD	1995-1998	Post 2005-2010
Furnace Sorbent Injection	1993-1995	Post 2000-2005
Duct Sorbent Injection	1994-1996	Post 2000-2005
NOx Control During Combustion	1996-1998	Post 2005-2010
NOx Control Post Combustion	1996-1998	Post 2005-2010
Integrated Gasification Combined Cycle	1996-1998	Post 2005-2010
Utility-Scale Atmospheric Fluidized Bed	1994-1996	Post 2000-2005
Pressurized Fluidized Bed	1998-2000	Post 2005-2010

*Assumes that the ongoing clean coal technology demonstration program continues; that a deployment program providing for several subsequent commercial-scale demonstrations of the same or similar technology will be fully implemented (number of deployment projects will vary by technology); that neither the demonstration nor deployment projects will fail; and, that deployment projects of the same generic technology will be initiated roughly in parallel and not in sequence to accelerate further the development schedule, (though the sequential approach would save dollars and permit maximum learning value from the prior projects). A successful deployment program is intended to provide sufficient operating experience with a given technology to establish technical feasibility, economic competitiveness with other commercially-available options, and qualified suppliers capable of guaranteeing the technology's performance.

**Assumes that industry will not be precluded from using the technology once it has been successfully demonstrated and deployed. To make a significant contribution to the reduction of atmospheric pollutants, the clean coal technologies must penetrate the market. Depending upon the degree of difficulty, size and complexity of each clean coal project or application, each commercial clean coal project will require 2 to 3 years from start date to placed-in-service date for simple engineering modifications and 5 to 7 years for projects requiring major equipment installation. Initially, to minimize risk, a utility will apply a retrofit or repowering technology to one or two units and not to the entire system. Once that utility gains experience and confidence in the technology it will likely be applied to other units in that utility's system. Each utility is likely to proceed in this same manner depending upon its individual, and unique, circumstances. Further, utilities will not all proceed to use such technologies at the same time. Therefore, significant market penetration which, in turn, will likely yield a significant contribution to the reduction of air pollutants, will take time and a decade beyond the date of commercial readiness is not an unreasonable estimate. Forcing use of the technologies through requirements for early reductions will only lead to abandonment of the newer technologies in favor of currently available technology, for example, wet-limestone scrubbers.

DISCUSSION

Mrs. LLOYD. Thank you very much, Dr. Markowsky.

I noticed in your statement that you have made major investment in pressurized fluidized bed combustion technology. This member certainly is impressed with the technology, not only because we can use high-sulfur coal, but because I think it will be cost-effective.

And I'm also concerned that it addresses some of the environmental concerns.

But I want to know what is your rationale for development. Do you see this as an ongoing technology development? Or, what were the specific goals that you wished to reach with fluidized beds?

Dr. MARKOWSKY. Madam Chairman, if I can go back to the time frame, we began pursuing the development of pressurized/fluidized bed combustion in 1976. At that time, we wanted to find a more cost-effective and environmentally effective technology as compared to a conventional plant with a scrubber.

We began that development with two foreign partners. We proceeded through the years with various test programs, to the point where, in 1980, we began specifically doing preliminary designs for a 70-megawatt pilot plant. And subsequent to that we applied under Clean Coal I and received cost-sharing in the amount of $60 million towards a program that is approximately $200 million, including our past work.

Mrs. LLOYD. You know, of course, the bottom line is that we have to be competitive with our energy supply if we're going to have a product or national security parallel with our allies or our competitors.

You mentioned that without the federal participation you can't reach these goals. But, yet, at the same time, utilities sort of have to reach these goals to sell power.

Isn't that true?

Dr. MARKOWSKY. That's right. That's the issue; that's a very difficult issue for us. In the past—and when I talk about the past, before 1960, when electricity rates were going down—it was easy for the utility industry and vendors to invest in new technologies because all the new developments basically were reducing the cost of electricity.

That is no longer the case. And also there were a number of orders being put forth at that time where vendors could afford to develop it.

Now, utilities are in the position where each new addition really increases the cost of electricity. And what we're trying to strive for is to moderate that increase.

In addition, the prudency issue before us with the Commission basically requires us to look at the lowest-cost options with respect to serving our customers.

So it's very difficult for electric utilities to take risks without some recognition of that risk by either the federal government from a cost-sharing point of view, as the DOE is doing under the Clean Coal program, or the Commission, where they're saying:

"We accept taking that risk. We know this might not end up being a low-cost option for the first plant. However, as you go with subsequent plants and that technology matures, the customer will eventually benefit."

But that's a very difficult issue right now at the State level.

Mrs. **Lloyd**. Do you intend to—do you see that the electric power industry will build more fossil plants in view of all the concerns of acid rain and environmental concerns?

Dr. **Markowsky**. I think there will be a combination of things that we'll have to build to meet the requirements of the forecasted demand.

Coal will definitely be the cornerstone of that. Right now, about 56 percent of the generation of electricity is coal light. I envision that increasing.

However, other technologies, like natural gas, combined cycle, will also come into play where they are appropriate in the economic picture, along with pump storage hydro, high facilities for peaking and, hopefully, we will be able to reinstate the nuclear options in the future.

Mrs. **Lloyd**. What kind of orders do we have now for fossil-fired fuel plants?

Dr. **Markowsky**. They are not that many. They're basically in the pipeline and they're going down. The new orders that are being put forth right now are for natural gas combined cycle power plant. Texas Utilities and Virginia Utilities just recently put forth major orders in those areas.

Mrs. **Lloyd**. What other Clean Coal technologies do you expect to use in the next 20-30 years?

Dr. **Markowsky**. Oh, I think the spectrum on the American Electric Power System—let me just stress that.

Mrs. **Lloyd**. The ones that will help us use the high-sulfur coal.

Dr. **Markowsky**. The three main ones for new generation will be pressurized/fluidized bed combustion, atmospheric fluidized bed combustion and integrated gasification combined cycle.

And those technologies are well along in both the demonstration and actually the deployment area. I think they will be major actors in the use of coal and they will enhance the use of coals and sulfur.

Mrs. **Lloyd**. It's basically the fluidized bed technology?

Dr. **Markowsky**. And gasification technology. Those are the three. The two fluidized bed technologies, and there's different variations of the fluidized bed technologies, and the gasification technology. Those are the new generation technologies that will be used for high-sulfur coal.

In addition, there will be advancements to scrubbers, which we call advanced scrubbers. And the advancement proposed there will allow the cost to go down somewhat and also improve the efficiency somewhat.

Mrs. **Lloyd**. Even though you're optimistic about the continued use of coal——

Dr. **Markowsky**. Yes, I am.

Mrs. **Lloyd** [continuing]. In new technologies, you as an industry, American Electric Power Industry, has certainly worked hard and embraced innovative power generation technologies. And you're continuing to do so.

But do you expect other utilities to respond to mandated emission restrictions if they don't participate in the technology development such as you have?

They aren't going to be prepared as you are.

Dr. **Markowsky**. Mandated emission reductions? I think to respond to that, the important issue there is the time frame. If mandated reductions are in the very near time frame, before the year 2000, I think that almost precludes Clean Coal technologies because, when you look at the time frame for the Clean Coal II programs, like our SPORN project, which is a 330-megawatt plant, that will go into operation in 1995.

The demonstration of that technology will go in operation at our facility in Ohio in 1990. What you need is to have another one of those types of plants built, and then the utility industry will gain the confidence because they'll be able to observe firsthand the operation and make an assessment as to the reliability. And after several are built, the cost of these technologies will go below the cost of conventional technologies with scrubbers.

So, yes, they'll use it. But, what we need to do is first be able to commercialize these technologies under a deployment program.

Mrs. **Lloyd**. Well, you're telling me that we're about 20 years from commercialization then.

Dr. **Markowsky**. We're between 10–20 years. After the year 2000, there's a time frame between 2000 and 2010, there will be significant penetration of all these technologies.

The more advancements like PFBC, their penetration will come in like 2005 with a significant penetration. There will be a few orders put in between '95 and 2005 after the SPORN operation and a few other programs. But significant penetration I do not envision before 2005.

Mrs. **Lloyd**. A decade of severe environmental problems.

Dr. **Markowsky**. I think we have to keep in mind that the trend of SO_2 emissions is downward. And as I mentioned, old power plants that are going to be 50 years and older after the year 2000, in that 10-year period, about 25 percent of all the generation will be 50 years or older and most of that is going to have to be replaced.

And when it's replaced, it's going to be replaced with technology that will meet new source performance standards. So it will be able to maintain that continued reduction in SO_2 emissions.

Mrs. **Lloyd**. Your testimony has been excellent. Thank you.

Mr. Morrison.

Mr. **Morrison**. I'd like you to describe for the record a little more detail on your working relationship with the Clean Coal technology program through the Department of Energy. You are through the Association participants in both Rounds One and Two.

Dr. **Markowsky**. That's correct.

Mr. **Morrison**. Could I have just a little better understanding of what you're doing under those two programs.

Dr. **Markowsky**. Under Clean Coal I we have our KID 70-megawatt demonstration program where we received approval for funding in February of 1987.

We have a cost-sharing grant of $60 million from the government; that program is $167 million. We right now in that program are actually in a construction phase. We have 50 percent of the steel of that facility already erected adjacent to our KID plant in Ohio.

That technology is pressurized fluidized bed which offers a 10 percent advantage in electric generation efficiency, plus it gives you a 50 percent reduction in nitrogen oxified emission.

In addition, another environmental advantage, it gives you about 15 percent less solid waste from the power plant, and that waste is a dry constituency. It's not like a sludge type waste from a scrubber plant.

So we're moving along very well in that program. A lot of the major components are nearing the completion of their fabrication. A 44-foot diameter, 70 foot tall pressure vessel right now is nearing completion in Mount Vernon, Indiana in the Babcock and Wilcox shop. That's scheduled to be shipped in May of this year to the site by barge.

The gas turbine for the combined cycle process is scheduled to be shipped in September. And we are going to go into pre-test operation there in June, July of next year.

Now, with respect to SPORN, which is the logical continuation of that technology, there we are taking an existing power plant where we have five units, we are taking two of those units—each are 150 megawatts, and replacing their boilers with a brand-new pressurized fluidized bed combustion boiler.

So we'll be generating steam for the existing turbines from this new boiler and the hot gas that's coming off the PFBC process will be driving a gas turbine, who will be generating about 20 percent of the energy from the gas turbine and 80 percent from the steam turbine.

That program timeline basically has us beginning detailed design toward the end of this year and continuing that design into the end of 1991.

Now, coincident with that design, we will have operating experience, at least one year of operating experience in the KID's building.

So we'll be able to feed back any sort of technology improvements that may be required as a result of the operation of the 70-megawatt KID's building into the SPORN design before we go into the actual procurement stage in 1992 and beyond.

If we can proceed on that kind of schedule, we then would envision having ground-breaking in the spring of 1993 and begin operation of that facility in the fall of 1995.

Mr. MORRISON. How has the Department been to work with?

Dr. MARKOWSKY. The Department has been excellent to work with. We've got a very good working relationship at the technical level and at the management level.

Mr. MORRISON. Have these proposals come from you or the Department that: Here's what we need to do?

Dr. MARKOWSKY. Basically, the proposal has been driven by what AEP started out in 1976 in our long-term development of this technology. It was fortuitous. We were ready at that point to consider a demonstration plant when a Clean Coal technology program was basically appropriated.

So the timing was ideal for the demonstration. And then when Clean Coal II came out, the time was ideal to pour the technology into the next logical step, where we would apply it at a commercial-sized facility and operate it under commercial conditions.

Mr. **Morrison**. Are you doing any projecting on cost per kilowatt hour out of these units?

Dr. **Markowsky**. Yes, we are. We basically right now for a commercial plant, in 1988 dollars, we're looking at something of the order of $1,600 a kilowatt compared to about $1,750 for conventional plant with scrubber.

Mr. **Morrison**. Just one last question on the greenhouse gases. If there's no way to burn coal, you've got to burn carbon fuels that you're going to keep from ending up with carbon in the atmosphere.

Is that something you folks in the coal industry sit around and sweat about? Or, are there answers? Or, are the savings in the acid rain area going to be sufficient to get us on through the foreseeable future?

Dr. **Markowsky**. It's a concern. There's a lot of controversy and I think the one thing, if you researched this area, one definite fact that I've been able to conclude is the CO_2 emissions are increasing.

But if I look back over time, and recently we've looked back many, many years, and it seems like it's definitely clear oscillation—when you go back to the Ice Age some 60,000 years ago, there was a significant depression in temperature. And 18,000 years ago, after the end of the Ice Age, the temperature rebounded. It rebounded about 2 degrees Centigrade.

Dr. Hanson of NASA presented some very interesting information where he looked at the 5-year average deviation from a 100-year average, if that's not too confusing. He took 100 years of temperature and averaged it and took a 5-year rolling deviation from that and showed a general trend of increasing except when he got to 1940, it seems like for the 20 years from 1940 to 1960, there was a decreasing trend.

So the issue is important. I think it's got to be considered. But I think it's got to be considered in the right perspective. It's a global issue. The United States basically contributes about 25 percent of the CO_2 emissions. However, we have 5 percent of the population, so we are a significant contributor.

But, if you look down the road with these under-developed countries, as they become industrialized, their contribution is going to be tremendous.

So what we've got to do is look at this issue from a global perspective and I think one aspect of the Clean Coal technology that's positive is that these technologies increase the efficiency of generating electricity, which basically, in essence, reduces the amount of coal you burn for the same number of kilowatt hours.

Mr. **Morrison**. That's encouraging and, of course, Congress is all caught up in the global warming issue. So that's the reason for my questions. I think you have some very reasonable answers.

Thank you, Dr. Markowsky.

Mrs. **Lloyd**. Thank you, Mr. Morrison.

Mr. Schiff.

Mr. Schiff. Thank you. Dr. Markowsky, I am Steven Schiff. I'm new to the Congress and to this Committee this year. I just have two things I'd like to ask you about, please.

You stated that you supported the Administration request in the areas for funding. In the areas I'm talking about, and as I look at the various Administration requests concerning coal, if not, in fact, virtually everything else, they're significantly down for the next fiscal year than what is being spent this fiscal year, if I'm reading the figures correctly.

Do you support that reduction?

Dr. Markowsky. I basically geared my statement toward the Clean Coal technology program, putting $600 million in fiscal '92 for Clean Coal Four and $600 million in fiscal '93 for Clean Coal V. That was the thrust of that remark.

Mr. Schiff. All right. What is the present funding for Clean Coal? How does that funding reflect today's funding in the same area?

Dr. Markowsky. Basically Clean Coal III is just under $600 million. That basically remains in tact. And Clean Coal IV and V were stretched out through fiscal '97. It brings it back.

And what it really does, it sends a very important message to the users and the producers of these technologies that there is going to be money available for the deployment of these technologies. And deployment is the key aspect to commercialize these.

You need to build three to four replications of this technology to get down the learning curve in order to refine the engineering and refine the manufacturing so we can basically reduce the cost. And also assure the industry that this is a reliable technology, so we ought to use it. Because of the situation we have in the States being a regulated industry, we are very—we're basically almost dissuaded from using a higher-risk technology. You're almost persuaded or forced into using a conventional technology that has little or no risk.

Mr. Schiff. Dr. Markowsky, there are proposals to require—as you pointed out, many plants soon will be 50 years old or older—there's proposals to require these plants to use scrubbers, or whatever the current technology can be added to the way they produce, burn coal now.

And there's proposals to require rate payers for consumption of electricity to pay an extra fee for that added technology. Out in New Mexico, our electrical company, the Public Service Company, which basically burns coal, I understand, objects to that, saying that they have already instituted the newer, newer technology. They put in scrubbers at their own cost, and they don't think that all consumers should pay when the rate payers have already paid.

I hope I'm clear in what I'm talking about here, and I wonder if the coal industry has a position on adding scrubbers to older producers and who should pay for it.

Dr. Markowsky. Well, I guess the issue of adding scrubbers to old producers, when you mentioned the 50-year old plant, a better way of handling those plants that are 40 or 50 years old is to repower them.

And what I mean by repower them, I mean replace the old boiler, because that's the part that wears out. And refurbish some of the other key components. And you repower it with a gas fire or an atmospheric fluid bed or a pressurized fluid bed.

Then you can get another 30 years operation from that facility and it will be relatively economic.

When you look at—it will be more economic than building a new one, but when you look at retrofitting an old facility with a scrubber, you take a facility that might have an embedded cost of zero, but it cost when it was built maybe $100 a kilowatt, and you're going to spend anywhere from $200 to $300 a kilowatt for a facility that might operate 5, 10, 15 years.

A lot of the industry will choose in that kind of scenario to actually look at retiring, prematurely retiring those types of facilities—if they do not have Clean Coal technology.

So I think the issue is to try to get these technologies in place so when those decisions need to be made, they can basically be made in an economic fashion.

Mr. SCHIFF. Thank you, Madam Chair.

Thank you, Dr. Markowsky.

Mrs. LLOYD. Thank you very much, Mr. Schiff.

And thank you for being with us today.

Dr. MARKOWSKY. Thank you.

Mrs. LLOYD. We now have a panel of witnesses who will discuss the fuel cell issue. Dr. Andrew Parker from Fuel Cell Association; Mr. Frank Schora from M-C Power Corporation, accompanied by Combustion Engineering; Mr. Michael Bergman, Director, Energy Research, American Public Power Association.

Thank you for being with us today. Mr. Parker, you're our lead witness.

PANEL 1: FUEL CELLS

STATEMENT OF ANDREW J. PARKER, JR., DIRECTOR, INDUSTRIAL FUEL CELL ASSOCIATION, WASHINGTON, DC

Mr. PARKER. Thank you, Madam Chairman.

Mrs. LLOYD. Good morning.

Mr. PARKER. It's nice to be here.

Mrs. LLOYD. We're glad to have you here.

Mr. PARKER. I've submitted a written statement, my résumé and my brief statement. So, if you would allow me to read my brief statement, I would appreciate it.

Mrs. LLOYD. And I'll tell all three of you that your complete statement will be made a part of the record, so you may summarize if you wish.

Mr. PARKER. Madam Chairman, my name is Andrew Parker. I'm here to testify as the Director of the Fuel Cell Association. I'm standing in for our President, Frank Spillers, who was unable to attend.

We appreciate the opportunity to testify today concerning the DOE FY-1990 Fuel Cell budget. My comments will concern the total fuel cell program, including fossil energy.

There are a number of concerns that we believe have the potential to dramatically impact our national energy posture. These include the environment, as has been mentioned; global warming and acid rain; electric power shortages in the near future; need for new, clean transportation fuel such as methanol; federal government abrogation of new technology demonstrations.

Fuel cells in our opinion are the best solution to providing power among all the currently known generating options because they're high-fuel efficiency and very low emissions.

The Fuel Cell Association believes the above-listed concerns are optimally resolved when related to the issues enumerated. The fuel cells are broadly deployed. Thus stress that the nation must place a higher priority on the widespread application of fuel cell technology.

Concerning the DOE FY-1990 budget, from the fossil energy program, we recommend phos-acid technology, funding of $6 million.

Phos-acid fuel cell technology is the most developed of all fuel cell technologies. Funding of $6 million seems critical at this stage to properly bring this technology to reality. The final push is needed for performance improvement and cost reduction to compete with competitive systems in the marketplace.

Molten carbonate, $20 million. FCA opposes the DOE budget request of $3.4 million for molten carbonate program. To maximize the successful potentials for a U.S. competitive position in this exciting new power generation option, FCA urges that all three current contractors be supported at funding levels consistent with their respective program.

We believe that $20 million provides the requisite encouragement to keep these efforts viable. FCA encourages industry/government cost-shared demonstrations be instituted as rapidly as possible.

Advanced concepts, $6 million. Monies are to support ongoing activities and solid oxide fuel cell research and to provide minimal support for investigation of additional new promising system concepts.

Advanced programs and technology development, $1.5 million. This support will provide an opportunity to perform basic and applied research at universities and with contractors on currently-identified problems; to investigate new materials and to study new, low-cost fuel cell concepts.

Cross-cut programs, $2.5 million. The present programs are not reaching the widest applications potential. Fuel cells are integral to small, large industrial and commercial markets. To fully exploit these potentials, DOE must become better equipped to introduce this new power system option to achieve conservation credits and offset the growing electricity demands for these unused sectors.

Fossil energy is in the best position to initiate cost-cutting effort. Therefore, the total fossil energy budget recommendation is $36 million.

Turning to the transportation conservation programs, we recommend a budget of $3.6 million. Support of this effort will allow Phase II of the Congressionally-mandated fuel cell battery bus program to proceed. This effort will require $2 million in funding.

DOE is in the process of initiating proton exchange membrane fuel cell technology for transportation application with the belief that PEM fuel cells could offer major improvements over the phos-acid fuel cell for the bus and other transportation applications.

$1.6 million is recommended for this program, of which $600,000 could be used to conduct R&D on membranes to the PEM fuel cell.

For DOE's energy storage program, we recommend $3 million to support proton exchange membrane fuel cell development and to develop the much-needed technology for direct oxidation and methanol.

Conservation of renewables should be funded at $2 million; $1 million in funding is recommended to evaluate the incorporation of fuel cells into commercial and industrial applications. Another $1 million is recommended to study incorporation of fuel cells into applications using hydrogen from renewable energy sources.

Thus, the grand total DOE budget recommendation is $44.6 million.

We would also like to make three other non-budget recommendations which FCA would be pleased to assist Congress in defining.

One, some form of federal government incentive should be offered to encourage the commercialization of fuel cells.

Two, Congress should establish a mechanism to review annually the worldwide development of fuel cell technologies. We feel that DOE and the Congressional Research Service could perform this function.

DOE should expand the participation of industry in establishing its long-range fuel cell plan.

In conclusion, fuel cells are the most energy-efficient devices currently available for converting fuel to electric power with the added benefit of very low environmental impact.

The U.S. has led in fuel cell development to date, but now it appears this lead will rapidly narrow as foreign governments increase their funding. Fuel cells will become a commercial technology. The only question now is:

Will the U.S. be an exporter or importer of fuel cell systems?

In addition, a loss of U.S. leadership in fuel cells will also result in a loss of many potential, high-technology spin-offs ranging from electronic conducting plastics to high-performance ceramics.

We feel we cannot afford more losses of U.S.-derived technology to foreign development.

Madam Chairman, we thank you for this opportunity today to present the Fuel Cell Association's viewpoint on government-sponsored development effort and the need to bring this important energy-producing technology to commercial reality.

[The prepared statement of Mr. Parker follows:]

FULL RECORD COPY

STATEMENT OF

ANDREW J. PARKER, JR.
DIRECTOR

FUEL CELL ASSOCIATION
WASHINGTON, D.C.

TO THE

UNITED STATES
HOUSE OF REPRESENTATIVES
SUBCOMMITTEE ON ENERGY RESEARCH & DEVELOPMENT

HEARINGS ON THE FY1990 FUEL CELL BUDGET
FOR THE DEPARTMENT OF ENERGY
HELD ON FEBRUARY 22, 1989

FY 1990 DOE FUEL CELL BUDGET RECOMMENDATIONS

Statement of the Fuel Cell Association

Madam Chairman, my name is Andrew Parker. I am here today to testify as a Director of the Fuel Cell Association. We appreciate this opportunity to comment on the FY1990 department of Energy Fuel Cell Budget. My testimony will cover the total DOE fuel cell program including Fossil Energy.

Summary

There are a number of concerns that have the potential to dramatically impact our national energy posture. These include:

1. Environmental (global warming, acid rain)
2. Electric power shortages in the near future
3. Need for new, clean transportation fuels such as methanol
4. Federal government abrogation of new technology demonstrations.

Fuel cells are the best solution to providing power among all of the currently known generation options because of their high fuel efficiency and very low emissions. The above-listed concerns are optimally resolved when related to the issues enumerated if fuel cells are broadly deployed. The Fuel Cell Association therefore believes that the Nation must place a higher priority on the widespread application of fuel cell technology.

Statement Details

This past year the national awareness of the deterioration of our environment has grown. Numerous legislative proposals were offered dealing with CO_2 increases in our planet's fragile atmosphere, alternative energy resources development including hydrogen, methanol and ethanol production incentives, and acid rain-causing pollution containment. The new Administration will likely have to define a course for the U.S. and seek world-wide cooperation in resolving these important items. While no one solution can answer all these challenges, fuel cells are, singularly, a significant part of the response. Fuel cells have inherent characteristics to mitigate the pollution problems while producing power at the highest electrical efficiencies currently available to our Nation, its industry and commerce.

Fuel cells operate as an electro-chemical converter. That is, unlike combustion-driven engines (diesels and turbines), fuel cells convert hydrogen-rich fuel gases directly into electricity. The high efficiency accrues due to the absence of friction-limiting moving parts and the very high reactivity of the chemical transformation leading to a complete reaction. Since there is nocombustion there are no acid rain-promoters. While still a controversial subject, CO_2 is considered a primary cause of the global warming/greenhouse effect. Carbon dioxide is a fuel cell waste product, however the amount produced is a fraction of that discharged by conventional power systems at an equivalent capacity; hence, a significant reduction in atmospheric CO_2 contribution is realized. Unlike internal combustion engines, fuel cell power is friendly to the environment.

The U.S. efforts in the field of fuel cells still lead the World, but with steadily increasing pressure and budgets by foreign interests, this position is being rapidly placed in jeopardy. Some even say the U.S. has already lost its lead. A major opportunity for U.S. leadership is to bring about a more balanced allocation of funding to include fuels other than coal gas. Funding for fuel cell development involving coal gas should continue, but other, more readily available fuels such as natural gas and methanol must be included. Use of these other fuel options, which are available now, can lead to a more rapid introduction of fuel cells into the world market which would return many-fold the U.S. government investment in fuel cell R&D.

Electric Utilities

Since the construction of new power plants has fallen behind, utility experts predict severe power shortages in the U.S. in the mid-90's. While shortages are being forecast, nuclear construction has faltered and coal-fueled plants are under increasing pressure due to environmental concerns such as acid rain. Fuel cells have the potential to solve many of the problems now facing our electric utility industry.

Fuel cells have no insurmountable technical barriers, but they must be allowed to come down the "learning curve" in terms of market acceptance and production costs. With less than a 20% uncertainty in molten carbonate stack cost estimates, plant installed costs of less than 1000 $/KW are very likely, which is a two-fold reduction in capital cost over conventional (coal/nuclear) central power stations. Further, operating at very high electric efficiencies, fuel cell power plants can deliver power at costs of 5-6 cents/KWh (1988 $'s) using natural gas and an even lower operating cost when eventually coupled to coal gasification. In a cogeneration application an additional credit of approximately 1 cent/KWh can be realized as the thermal energy by-product is a high quality source for direct process heat, representing between 20-30% of the input energy from the fuel source.

The U.S. dominance of power generation equipment markets is eroding as other countries aggressively fund total ("womb-to-tomb") programs, including scaled demonstrations. Our military procurements commonly include such phases, a major reason for U.S. superiority in weapon systems. By contrast, demonstrations using Federal cost-sharing during the equivalent civilian R&D stage have been considered inappropriate. The U.S. is floundering at precisely the last and most critical stage of development, prototype demonstration.

The target markets for fuel cells are vast and include gas and electric utilities and independent power producers, along with private enterprises. These users are very conservative, low risk-takers. The privately supported research agencies-EPRI, GRI, and APPA, do not have adequate funds to go it alone. The Federal government must create and fully support new technology demonstrations able to respond to national energy needs, much as the DOD evaluates new weapon systems for our defense. Not to do this means loss of U.S.-developed advances to overseas' manufacturers where they will be produced and exported back to us.

Concommitantly, industrial employment, profits and balances of trade are also lost. We have seen this affect our automotive, electronic and computer industries, among others. When are we going to wake up to the fact that the U.S. dominates new product discoveries, but we let others bring our technology to commercialization?

Transportation

Particular emphasis by Congress should be given to the use of fuel cells in the U.S. transportation sector as a possible replacement for the internal combustion (IC) engine. IC engines for transportation account for 63% of U.S. oil consumption and are a major source of environmental pollutants, especially in major urban areas. Fuel cells offer the chance to significantly reduce this enormous energy use by our national transportation system and to significantly reduce the environmental impact.

The transportation use of fuel cells is undoubtedly the most difficult among all potential applications of fuel cells and without innovative government encouragement it may never happen in the U.S. It is recommended that Congress and the Administration foster Industry/Federal cooperative programs to speed the application of fuel cells to our critically important transportation sector. Some of our members stand ready to participate in discussions about such cooperative programs.

Turning to the FY1990 Budget, the FCA presents its suggestions and rationale in the following paragraphs for the DOE Fuel Cell Programs.

DOE BUDGET RECOMMENDATION

I. Fossil Energy

A.	Phosphoric Acid Technology	$ 6 Million

Phos Acid Fuel Cell Technology is the most developed of all fuel cell technologies. Funding of $6 million is critical at this stage to properly bring this technology to reality. A final push is needed for performance improvement and cost reduction to compete with competitive systems in the market place.

B.	Molten Carbonate	$20 Million

FCA strongly opposes the DOE Budget Request of $3.4 million for MCFC programs. To maximize the success potentials for a U.S. competitive position in this most exciting new power generation option, FCA urges that all three contractors be supported at funding levels consistent with their respective program needs. We believe that $20 million provides the requisite encouragement to keep these efforts viable. FCA urges industry/government cost-shared demonstrations be instituted as rapidly as possible.

C.	Advanced Concepts	$ 6 Million

Monies are to support on-going activities in Solid Oxide Fuel Cell (SOFC) research and to provide minimal support for investigation of additional new promising system concepts.

D.	Advanced Programs and Technology Development	$ 1.5 Million

This support will provide an opportunity to perform basic and applied research at universities and with contractors on currently identified problems, to investigate new materials, and to study new low cost fuel cell concepts.

E. Cross-Cut Programs	$ 2.5 Million

The present programs are not reaching the widest applications potentials. Fuel cells are integrable to small/large industrial and commercial markets. To fully exploit these potentials, DOE must become better equipped to introduce this new power system option to achieve conservation credits and offset the growing electricity demands from these end-use sectors. Fossil Energy is in the best position to initiate cross-cutting efforts.

Total for Fossil Energy	$36 Million
II. Transportation/Conservation	$ 3.6 Million

Support of this effort will allow Phase II of the congressionally mandated fuel cell/battery bus program to proceed with the 20 passenger urban prototype test bus with phosphoric acid fuel cells. This effort will require $2 million in funding.

DOE is in the process of initiating Proton Exchange Membrane (PEM) fuel cell technology for transportation applications. The PEM fuel cell could offer major improvements over the phosphoric acid fuel cell for the bus application. DOE is negotiating a contract with a major auto manufacturer with 50% cost-share. This technology could lead to the eventual use of fuel cells for transportation. It is recommended that the Congress add $1.6 million for this program, of which $600K could be used to conduct R&D on membranes for the PEM fuel cell.

III. Energy Storage	$ 3 Million

Energy Storage should be funded at $3 million to support Proton Exchange Membrane fuel cell development and develop the much needed technology for the direct oxidation of methanol. Following the past success of government/industry joint funding of this program, with a major U.S. auto manufacturer, emphasis should be given to funding other joint industry/DOE development projects--for example, applied research on membrane phenomena, optimization, and characterization.

IV. Conservation and Renewables	$ 2 Million

$1 Million in funding is recommended to evaluate the incorporation of fuel cells into commercial and industry applications using the basic technology now being developed for utility size plants. Also, $1 million is recommended to study the incorporation of fuel cells into applications using hydrogen from bio-fuels, wind energy, photovoltaic, and other renewable sources.

Grand Total	$44.6 Million

Recommendations

In addition to the foregoing budget recommendation:

1. Beyond direct R&D budget support, it is recommended that some form of Federal government incentive be offerred to encourage the commercialization of fuel cells. FCA would be pleased to assist in defining incentives that could stimulate industry to develop and use fuel cells.

2. It is highly recommended that Congress establish a mechanism to annually review the worldwide development in both the technical and commercial aspects of fuel cell efforts. Particular emphasis should be given to U.S. developments. Since DOE has access to the government sponsored programs, they would be the likely choice to prepare the annual report on U.S. activities. The Congressional Research Service should be requested to summarize non-U.S. activity.

3. DOE should expand the participation of industry in establishing its long-range fuel cell plans.

Conclusion

Fuel cells are the most energy efficient devices currently known for converting fuel to electrical power with the added benefit of very low environmental impact. The U.S. has led in fuel cell development todate, but now it appears this lead will rapidly narrow as foreign governments have recognized the advantages of fuel cells and are increasing their funding levels. Fuel cells will become a commercial technology; the only question now is will the U.S. be an exporter or importer of fuel cell systems? In addition, if U.S. leadership in fuel cell development is not strengthened, there will also be a loss of commerce in fuel cell technology spin-offs such as:

1. Electrically conducting plastics
2. Ceramic fabrication
3. New catalysts
4. Corrosion resistant materials
5. Superconductors

These spin-offs will result in revolutionary products in such areas as medical, electrical control systems, chemical processing, electrical transmission and scientific equipment, to name a few.

Thank you for this opportunity to present the Fuel Cell Association's viewpoint on the development effort needed to bring this important energy producing technology to commercial reality.

2/7/89

Mrs. LLOYD. Thank you very much, Mr. Parker.

Mr. Schora.

STATEMENT OF FRANK C. SCHORA, PRESIDENT, M-C POWER CORPORATION, CHICAGO, IL

Mr. SCHORA. Thank you, Madam Chairman and members of the Subcommittee. I'm Frank Schora, President of M-C Power Corporation, a company solely formed for the purpose of scaling up and commercializing the molten carbonate fuel cell.

A new concept is being used known as the IMHEX design, which should significantly reduce the cost and complexity in the evolution of the technology from laboratory to commercial sites.

M-C Power was created in 1987 and is now a capitalized, multi-shareholder-owned corporation. The Institute of Gas Technology has contributed its IMHEX technology and future technical support for a share of the corporation. Other shareholders have contributed the necessary capitalization.

Since it has been established with this one goal and has stockholders investing because of their interest in this goal, M-C Power will be very efficient in pursuing its objective.

An integrated coal gasifier, molten carbonate fuel cell power plant can use coal to produce electricity at an efficiency approaching 55 percent compared to 33 percent for conventional coal-based systems. Using the actual gases fuel it is possible to achieve efficiencies in excess of 60 percent. Its module in nature allows its use in a wide range of sizes and applications from small, on site natural gas by co-generation systems to coal-fuel, base-loaded power plants.

No other known device can achieve these efficiencies.

The molten carbonate fuel cell system can be used to retrofit older coal-fired power plants. Such a system can achieve a 99.95 percent reduction in SO_x and an 84 percent reduction in NO_x.

For a new molten carbonate fuel cell power plant which would have a coal to electrical power efficiency of 55 percent, a 42 percent reduction in both fuel consumption and carbon dioxide emissions can be realized when compared to a conventional coal-fired plant.

Such an efficiency gain can have a significant impact on reducing the greenhouse effect. Increasing the efficiency is the best way to reduce the CO_2 problems.

To assist this, M-C Power has created an advisory group consisting of representatives of several utilities and industrial companies interested in future power generation.

Our prime objective will be to scale up to commercial size and manufacture fuel cell stack. In pursuing this goal, we're working under a DOE contract with IGT and Combustion Engineering.

When I reported to this Subcommittee last year, I mentioned our new IMHEX concept. I'm pleased to report that two one square-foot stacks have been designed, fabricated and tested this last year based on this concept and have performed to expectation.

In order to meet our schedule which should see introduction of commercial sized stacks for demonstration in FY-94, we are now planning for the installation of the larger equipment necessary for the manufacture of component.

We've just moved into a new building located in Burr Ridge, Illinois, which will house these prototype manufacturing facilities.

Thanks to the assistance of this Subcommittee, we have the funding necessary to carry this program through to the end of FY-89. We anticipate that three additional years will be necessary to see us into actual prototype production.

Because scale-up of Molten Carbonate Fuel Cell systems is underway by three DOE contractors, each pursuing the objective on a different design basis, we feel it is not appropriate to select a single approach at this time, but to fund each of the three contractors at an $8 million level for FY-90.

This $24 million will be well-spent as funding levels in other countries for this very promising technology will be significantly higher. In the out-years, M-C Power presently anticipates funding requirements of $10 million in FY-91 and $12 million in FY-92, at which time, large, commercial-sized stacks should be under test.

At that time, M-C Power would look to participation in a Clean Coal program.

I thank you for the opportunity to appear here today and would be happy to answer any questions.

[The prepared statement of Mr. Schora follows:]

([illegible])

Statement by Frank C. Schora, President, M-C Power Corporation
House Committee on Science, Space and Technology
Subcommittee on Energy Research and Development

February 22, 1989

Mr. Chairman and Members of the Subcommittee:

My name is Frank Schora. I am president of M-C Power Corporation, a company formed for the purpose of scaling up and commercializing the Molten Carbonate Fuel Cell System. A new concept is being used, known as the IMHEX^{tm} design which should significantly reduce the cost and complexity in the evolution of the technology from laboratory to commercial size.

M-C Power, created in 1987 is a capitalized, share holder owned corporation. The Institute of Gas Technology (IGT) has contributed its IMHEX^{tm} technology and future technical support for a share of the corporation. Other shareholders have contributed the capitalization necessary for M-C Power to aggressively pursue its goal.

Since it has been established with this one goal and has stockholders investing because of their interest in seeing the corporation achieve this commercialization goal, M-C Power will be particularly focused and consequently very efficient in pursuing this objective.

A molten carbonate fuel cell electrochemically reacts fuel and air to directly produce electricity. An integrated coal gasifier/molten carbonate fuel cell power plant can use abundant domestic coal to produce electricity at an efficiency approaching 55% compared to 33% for conventional coal based systems and 45% for other advanced electric power generating concepts. When using natural gas as fuel, it is possible to achieve efficiencies in excess of 60% with certain system configurations. Its modular nature allows its use in a wide range of sizes and applications, from a few hundred kilowatts to multi-megawatts and from small on-site natural gas fired cogeneration systems to coal fueled baseload utility power plants. Because a molten carbonate fuel cell operates at 1200°F, waste heat produced as a by-product of the electrochemical reactions can be recovered at sufficiently high temperatures to allow a wide range of use in cogeneration and industrial applications.

A molten carbonate fuel cell system can be used to retrofit older coal fired power plants. An independent system analysis showed that such a coal gasification/molten carbonate fuel cell system can achieve a 99.5% reduction in SO_x and an 84% reduction in NO_x. For new molten carbonate fuel cell power plants which would have a coal to electrical power efficiency approaching 55%, a 42% reduction in both fuel consumption and carbon dioxide emissions can be realized when compared to a conventional coal fired steam power plant. Such an efficiency gain can have a significant impact on reducing carbon dioxide additions to the atmosphere and thereby could lessen the possible greenhouse effect.

The successful development of molten carbonate fuel cell systems will provide significant benefits to the United States. In addition to its fuel conserving high efficiency and its essentially pollution free operation, it will enable the U.S., to develop as the need arises, on site ie. already distributed power generation for sale either by the utilities or by cogenerators. This locally generated power will decrease the need for; 1) siting major new power plants and 2) significant installation of new electrical power distribution systems. We must recognize that the public is becoming generally adverse to perceived environmental and health issues which consequently make permitting increasingly difficult.

M-C Power has created a Program Advisory Group consisting of representatives of several utilities and industrial companies interested in future power generation. This group recently held its first meeting at which representatives from DOE, the Electric Power Research Institute and the Gas Research Institute were present. The group will assist us in guiding our development work so that we will create molten carbonate fuel cell systems which will be of maximum benefit to the country.

M-C Power's prime objective will be to scale up to commercial size and manufacture molten carbonate fuel cell stacks. Our plans are to build stacks based on individual cells having a cross sectional area of about 8 sq. feet. A fuel cell stack consists of such cells stacked one on top of the other so that the required electrical power output can be achieved.

M-C Power is working under a DOE contract with IGT and Combustion Engineering to develop the IMHEX™ concept. IGT, who has been the pioneer in the development of the molten carbonate fuel cell concept, will continue its R&D activities and will work toward improving components using the least expensive materials commensurate with the cell endurance necessary for commercial acceptance.

Combustion Engineering (CE) will focus on the areas of design and manufacture of the fuel cell stack support systems. Their responsibilities will involve optimization of the support system design for both low power cogeneration systems as well as large multimegawatt coal based systems. They will also provide engineering and manufacturing assistance to M-C Power in the stack development activity. In the future, Combustion Engineering will provide the marketing and sales strength to M-C Power under a separate agreement. Combustion Engineering is one of the largest world wide fabricators and suppliers of coal based electric power generating systems and has an excellent understanding of industry needs and how to effectively market in this area.

When I reported to this subcommittee last year, I mentioned our new concept of molten carbonate fuel cell and stack design which our team had termed "IMHEX". It is coined from the concept of internally manifolded heat exchangers. I am pleased to report that two 1 sq. ft. stacks have been designed, fabricated and tested based on this concept and have performed to expectation. These tests indicate the concept is sound, that fabrication of the separator plates which were based on the actual stamping requirement of a large commercial size plate is possible and appears to be cost effective based on ongoing manufacturing studies. What was also learned from these first two successful tests was that the use of internal manifolding of gases within the stack, which is being pioneered in the U.S. by the M-C Power team, has many benefits in overcoming some of the problems, such as external manifold leakage which the older designs encounter with aging and shrinkage of the stack components over prolonged operation. Manifolds conduct the fuel and oxidant gases to the individual cells that make up the stack. Also internal manifolding greatly improves the ability to accurately load the stack with the necessary electrolyte.

In order to meet our schedule which should see the introduction of commercial size stacks for demonstration and prototype application in the FY 94 time frame we are now planning for the installation of the larger equipment necessary for the manufacture of components. We plan to move this month into a new building in Burr Ridge, Illinois which will house these prototype manufacturing facilities and the necessary large scale test stands.

Thanks to the assistance of this subcommittee and others, we have the funding necessary to carry this program through the end of FY 89. We anticipate that three additional years will be necessary to see us into actual prototype production of these commercial size stacks which will be tested both at our facilities and by interested co-generators and utilities.

Because scale-up of Molten Carbonate Fuel Cell systems is underway by three DOE contractors, each of which is pursuing this objective on a different design basis, we feel it is not appropriate to select a single approach at this time but to fund each of the three contractors at an $8 million level for FY 90. This $24 million will be well spent, as funding levels in other countries for this very promising technology will be significantly higher. In the out years M-C Power presently anticipates funding requirements of $10 million in FY 91 and $12 million in FY 92 at which time large commercial sized stacks should be under test. At that time, M-C Power would look to participation in a clean coal program to see this new power generating concept to commercial realization.

I thank you for the opportunity to appear before this subcommittee and would be pleased to answer any questions.

Mrs. Lloyd. Thank you very much.

Mr. Bergman.

STATEMENT OF MICHAEL BERGMAN, DIRECTOR, ENERGY RESEARCH, AMERICAN PUBLIC POWER ASSOCIATION, WASHINGTON, DC

Mr. **Bergman**. Good morning, and thank you, Madam Chairman.

My name is Mike Bergman. I'm the Director of Energy Research for the American Public Power Association. APPA is the national service organization that represents the interests of 1,750 locally publicly-owned electric utilities throughout the United States.

I appreciate the invitation to appear today to comment on APPA's recently-issued notice of market opportunity for fuel cells and discuss with the Subcommittee why Public Power believes fuel cells to be an important technology in our energy future.

I also appreciate being a part of this panel and, hopefully, sharing with you a user's perspective on why fuel cells are of interest to the electric power industry.

In excess of 35 million Americans, more than one in seven are served power by 2,200 local community-owned electric utilities located in 49 of the 50 States.

Public Power in the United States is the second largest segment in the nation's diverse electric power industry and provides power to approximately 15 percent of all consumers, with a net investment greater than $52 billion.

APPA and many of its members have been active in efforts to promote the development of fuel cells for more than a decade. The kinds of efforts have varied from support for continued R&D funding, participation with users' groups, to commitments for hosting multi-megawatt demonstrations or securing orders for early market entry units.

However, most recently, the failure of an effort to demonstrate three or four 11-megawatt power plants that was being spearheaded by the Electric Power Research Institute has alarmed the Public Power community and led to a new initiative.

This new initiative was APPA's issuance of its notice of market opportunity for fuel cells, which I did submit with my written testimony and would like to make sure, Madam Chairman, that it is included in the record, if I may so request.

This 100-page document is not a request for proposal. What it is rather is an invitation to perspective fuel cell manufacturers of our interest in working collaboratively with them to find workable and cost-effective schemes for early commercialization of fuel cells.

We issued this document in October of 1988 and requested responses from manufacturers by February 1st. Those responses are now in. They have not been in for long so I cannot characterize them for you in any detail, but I can summarize for you that we did receive six bona fide responses to work with us in promoting early commercialization. Those responses were from Japan, Europe and the United States.

The technologies that were offered in those responses, three of them were phosphoric acid in design, two were molten carbonate and one was solid oxide.

APPA's experience with two now abandoned multi-megawatt demonstrations and the lessons that we have learned through the preparation of our notice of market opportunity and the responses to it form the thrust of my comments today.

In essence, my message can be distilled into six key points. First, there is a market for fuel cells within the electric power industry and it is significant.

Second, Public Power is an eager market and willing to help catalyze through many different options the early commercialization of fuel cells.

Third, potential manufacturers must share the risks and cost of demonstrating those fuel cells.

Fourth, there is an energy demonstration gap basing fuel cells and other advanced energy technologies, and that is a gap that the private sector cannot carry alone.

Fifth, now is exactly the wrong time for the federal government to cut back on its fuel cell R&D.

And, finally, we believe a new approach is needed to bring advanced energy technologies to market.

These points are elaborated in my written comments, but let me emphasize a few of the points and key messages here.

First, let me address market potential. In last year's Senate report for Interior and related agencies' appropriations, that is, for fiscal year 1989, the statement was made that, quote:

"Despite the substantial expenditures . . ." namely, referring to almost a billion dollars in public and private monies for fuel cell R&D, the quote continues ". . . no significant market has developed for utility scale applications." End quote.

APPA could not disagree more strongly. What we have seen is a failure of marketing, high initial cost hurdles accompanied by technical risk and a lack of leadership and innovation in finding workable commercialization strategies, but the market potential is significant.

APPA's own market study conducted by ourselves has identified 10,000–30,000 megawatts potential cumulative capacity over the next 15 years within Public Power alone.

Perhaps another 40,000 megawatts potential or more exists in the rest of the electric industry.

These potentials do not include smaller units more suitable for commercial, industrial or transportation markets.

Second, another key message. With respect to Public Power's interest in fuel cells, we see ourselves as a significant player but insufficient alone to establish the market pull necessary for commercialization.

However, because of the unique fit we see between fuel cells and many of the strategic challenges facing our members, we are attempting to discover a new market-driven approach through our notice of market opportunity that will help speed commercialization.

If I may, let me share with you some of the strategic changes affecting Public Power that are driving this interest.

An increased competition within the electric power industry and with natural gas; the current over-reliance on wholesale power supply by our members from private utilities; challenges to traditional federal power marketing arrangements; increasingly stringent environmental requirements with further tightening likely due to global warming and other concerns; continuing limitations on transmission access and difficulties in building new transmission lines; and tax restrictions on Public Power's ability to finance large-scale generation with private utilities, a strategy employed frequently in the past for growing into new capacity.

In short, we foresee what we are terming a power supply vice facing our members in the future. The fuel cell, with its smaller-scale, modularity, short lead times, high efficiency, superior environmental performance, desirable operating characteristics and suitability to cogeneration is a most attractive, if not the most attractive, advanced generating technology that we can see on the horizon.

I would refer you to Appendix D in this document, the Notice of Market Opportunity, for a more detailed description of how APPA perceives the fuel cell's unique benefits.

A third key message that we believe all parties with an interest in fuel cells—the buyers themselves, namely, groups such as Public Power; the manufacturers, such as the interests up here at the table; and the federal government have much to gain from the commercialization of fuel cells.

From the buyer's perspective, an acceptable new option that meets energy, economics, environmental and societal concerns deserves up front financial and marketing assistance.

Public Power is prepared to consider these roles as well as a variety of others, depending on how our discussions with manufacturers as a result of our Notice of Market Opportunity ensue.

From the suppliers' or manufacturers' perspective, fuel cells, like other emerging and modular energy technologies, perhaps such as photovoltaics, will be characterized by grade economies of scale in the manufacturing.

The more that are made, the cheaper they will be. If the initial commercialization is successful, huge profits stand to be made.

Furthermore, the first manufacturer to offer a commercially viable fuel cell would generate substantial cash flow for continuing technology improvement that will make it very difficult for other perspective manufacturers to enter the market and compete.

In recognition of these potential gains, manufacturers should share in the risks and the costs of technology demonstration in early commercialization.

From the perspective of the federal government, though nearly $450 million has been spent to date on fuel cell R&D, APPA believes that the U.S. is at risk of losing its technological leadership. We cannot share with you some of the proprietary information and the responses that we received to the Notice of Market Opportunity, but I would as just an example share with you anecdotally:

Five years ago, the common understanding within the United States is that our nearest competitors were at least five years behind. In some key technical areas, those foreign competitors have drawn even or now surpass some of the capabilities of domestic manufacturers.

The very real prospect is that advances pioneered in the United States will be packaged and sold back to us by foreign competitors, further worsening the nation's trade deficit and eliminating what had been excellent, expert opportunities.

More importantly, an advanced energy option for meeting energy and environmental goals may not be ready for adoption when needed.

Fuel cells, like other advanced energy technologies face a high first cost hurdle. Our nation faces a critical energy technology demonstration gap. Each of the key players—government suppliers and markets or buyers—is needed, but insufficient alone to secure such demonstrations, public/private partnerships must be forged to address our nation's critical energy demonstration gap.

Thus, in conclusion, APPA suggests a new approach to energy demonstration. Retain the current approach of line item appropriations for basic and applied R&D, but create a new fund for cooperative demonstration ventures for all advanced energy technologies; provide sufficient time for cooperative ventures between manufacturers and buyers' consortia to develop, and then let each of these ventures compete for available monies in the fund.

The basic outlines of this approach are offered in my written comments. APPA believes this approach holds the greatest prospect for limited federal energy dollars to achieve the largest tangible results. It is fair and market-driven. We believe it would be enthusiastically supported by other energy markets, and it addresses the nation's critical energy technology demonstration gap.

Thank you and I'll be pleased to answer any questions.

[The prepared statement of Mr. Bergman, plus APPA's issuance of its notice of market opportunity for fuel cells follows:]

AMERICAN PUBLIC POWER ASSOCIATION
2301 M STREET NW WASHINGTON DC 20037 • 202/775-8300

Testimony on

DOE'S FY 1990 BUDGET REQUEST FOR FOSSIL R&D AND CLEAN COAL TECHNOLOGY

before the

Subcommittee on Energy Research and Development
Committee on Science, Space and Technology
U.S. House of Representatives

submitted by the

American Public Power Association
Washington, DC 20037

February 22, 1989

The American Public Power Association (APPA) is pleased to submit testimony on DOE's FY 1990 budget request for Fossil R&D and the Clean Coal Technology Demonstration programs at the request of the House Subcommittee on Energy Research and Development. APPA's comments focus on our recently issued "Notice of Market Opportunity for Fuel Cells" (NOMO) and why public power believes fuel cells to be an important technology in our energy future.

APPA is the national trade association that represent 1,750 local publicly owned electric systems throughout the United States, Canada, Puerto Rico, American Samoa and Guam. Public power constitutes the second largest segment of the electric utility industry in the United States, serving 35 million Americans in all states save Hawaii. Most public power systems are small utilities, typically serving communities of under 10,000 population.

APPA's comments are summarized in the six points below, followed by more detailed comments on each point. Forwarded with our testimony is a copy of our 100-page NOMO, the content of and responses to which provide essential background to our comments. Our testimony ends with summary conclusions and recommendations.

SUMMARY

APPA's main comments can be distilled into these six points:

- First, there is a market for fuel cells, and it is a significant one. APPA estimates that the cumulative "likely, early" market potential for megawatt-scale fuel cells within public power alone in the period 1996-2010 to be 10,000 MW to 30,000 MW. Environmental, economic, energy and societal trends, moreover, suggest the market potential for fuel cells will only increase;

- Second, the public power market is an eager one, due to the fuel cell's ability to address many of the strategic challenges facing APPA's members. As a tangible expression of our interest and willingness to assume leadership, APPA and its members have issued a "Notice of Market Opportunity for Fuel Cells," enclosed with our testimony, which invites manufacturers to work collaboratively with public power to help speed commercialization. Possible steps that public power is willing to consider in this role are discussed below;

- Third, fuel cell manufacturers are eager to work with potential markets to develop innovative commercialization strategies. Six formal responses were received to APPA's "Notice of Market Opportunity" invitation from manufacturers in the in the U.S., Japan and Europe. Phosphoric acid, molten carbonate and solid oxide fuel cells were proposed. In addition, other letters of interest from potential manufacturers that are not as far along in their technology development efforts were also received;

- Fourth, the environment for commercializing new energy technologies has changed -- forever. Manufacturers are no longer willing or able acting alone to bring new technologies to market. The budget deficit dictates a different role for the federal government than what was possible during the heyday of energy funding in the late 1970s. The markets themselves face increased competition and are unwilling to pay undue cost premiums for new technologies. Public-private partnerships must be forged to address this energy technology "demonstration gap;"

- Fifth, therefore, now is absolutely the wrong time to be cutting federal support for needed fuel cell demonstrations. After expending nearly $1 billion for fuel cell R&D, approximately $450 million of which from the federal government, America's leadership in fuel cell technology is at risk. Again, many other emerging energy technologies face this critical "demonstration gap." Being penny wise and pound foolish at this juncture only means that our domestic markets will turn to overseas suppliers;

- And, sixth, the crafting of APPA's NOMO and the responses to it suggest the need for a new approach for how priorities can be set and how funding can be earmarked for other emerging energy technologies.

Each of these points is elaborated upon below.

THE MARKET FOR FUEL CELLS IS SIGNIFICANT

In the Senate 1989 appropriations report for Interior and Related Agencies, the statement is made that, "Despite these substantial expenditures [of public and private monies for fuel cell R&D], no significant market has developed for utility-scale applications." APPA and its members strongly disagree with this assessment.

At least a dozen studies of the market potential for fuel cells within the electric utility industry have been conducted since the mid-1970s. Study methods have widely varied, but estimates of cumulative market potential over, say, a fifteen year period have ranged from about 15,000 MW to 100,000 MW. The median market potential is in the range of 40,000 MW to 45,000 MW, or about 7 percent of all currently installed electric generating capacity in the U.S.

Due to our belief that many of these prior studies had given inadequate attention to the role and needs of public power systems, APPA began its own market assessment in 1988. Preliminary results from that study are reported in Section II and Appendix E of the accompanying NOMO. The final market study will be published in March 1989.

The "likely, early" market potential within public power in the period 1996-2010 is about 30,000 MW. When matched with our understanding of commercial fuel cell prices, APPA foresees a realistic potential of about 10,000 MW in that same time period.

These cumulative megawatt potentials are for public power systems only, and appear in line with the electric utility industry-wide potentials noted above. And these potentials, of course, do not include the potential for kilowatt-scale fuel cells which are the focus of the gas industry for the commercial or industrial cogeneration markets or of other interests for the transportation market.

Clearly -- if adequately demonstrated and if appropriately priced -- fuel cells can make significant contributions throughout the U.S. energy economy. But these "ifs" are big ones, and are the focus of our remaining comments.

In many respects, fuel cells are a "niche" technology. This niche is characterized by the need for superior environmental performance, for high efficiency and cogeneration potential, and for unique operating flexibilities, plus by the requirement of adequate natural gas supplies at acceptable costs. This niche is most often found in urban locations, though increasingly stringent standards of environmental performance are broadening this niche to many other parts of the country.

APPA believes that the seeming lack of market interest quoted at the beginning of this section is in part due to the marketing failures of the manufacturer (among other factors), not the absence of willing buyers. No buyer is willing to assume both high financial and technical risk, as earlier "commercial" offerings proposed.

FUEL CELLS FIT MANY OF PUBLIC POWER'S STRATEGIC CHALLENGES

The unique benefits promised by fuel cells provide a strategic answer to many of the challenges facing public power. This section summarizes those benefits and challenges.

The Unique Benefits of Fuel Cells. Fuel cells promise unique benefits to public power communities. They are clean, quiet, siteable in urban areas, and can be construction in months rather than years. Their modular design may act to increase reliability and lessen risk by allowing "building block" expansion, and shorter planning horizons. Unique operating capabilities include responsive load following, rapid ramp rates, power factor improvement (reactive power compensation), and system protection. Electrical efficiencies are high with excellent prospects for further improvement. And, they are well-suited for cogeneration.

Appendix D in the accompanying NOMO is a more detailed description of APPA's understanding of these unique benefits.

Evolving Trends in the Electric Utility Industry. The decade of the 1980s has been a period when the concepts of "deregulation" and "competition" moved out of academic classrooms to political back rooms. Trucks, phones, banks, airlines, and most recently, natural gas have become deregulated. Over the last year, serious consideration has been given in the U.S. Federal Energy Regulatory Commission (FERC) to deregulate electric utilities through administrative action.

Currently pending are FERC proposals apparently intended to do three things: (a) make it clear that electric utilities do not have to buy capacity they don't need or to pay prices which are unrealistic for electricity produced by cogenerators and small power producers; (b) encourage use of competitive bidding in the acquisition of any power purchased; and (c) relieve "independent power producers" -- non-utility generators -- and private power companies from FERC regulation under certain conditions.

If such proposals become law, there are numerous ramifications in their details that could place many public power systems at a competitive disadvantage, especially those that now depend upon a well-regulated bulk power supply market. Even if these proposals do not become law, they are harbingers of many other trends within the industry.

For example, increased competition is occurring in the power industry as witnessed by: the growth of third-party cogenerators; mergers and consolidations by private utilities; attempts by private utilities to buy out public power systems; attacks on the historical methods by which power from federal dams is allocated or licenses for new or existing dams are granted; and competition between utilities for new industrial customers or annexation of service territories. As the regulatory compact between state utility commissions and their regulated utilities changes, new experiments in market-based bidding programs, on the one hand, and more proscriptive least-cost planning requirements, on the other, are becoming prevalent.

Competition in the electric utility industry is here today. And all signs point to increased competition in the future.

Transmission Access and New Lines Are a Major Uncertainty. Three-quarters of public power systems have no generation. Their flexibility in purchasing the wholesale power they distribute is critically dependent on access to transmission. Yet public power systems currently own fewer than 10% of the U.S. electric transmission system. Access to transmission by the large majority of public power systems depends on their ability to negotiate contracts on their own or through a joint action agency, or to secure it through lengthy and expensive judicial proceedings. More than 80% of the nation's transmission circuit miles are owned by about 180 private utilities.

The importance of the bulk power market has grown tremendously in recent years. Today, at least 30% of total power sales in the United States occurs through the bulk (transmission-dependent) market. Individual public power systems depend on purchased power for almost 85% of their total sales to ultimate customers.

Yet if access is limited, or the building of new lines is constrained due to questions of public acceptance, economies to be gained in the bulk power market are foreclosed. And, should generation be further deregulated without ensuring equitable access to transmission, the competitive squeeze for many smaller utilities could be fatal.

Self-generation thus becomes an important option in its own right and as a bargaining lever to secure access to transmission controlled by private utilities.

Environmental Concerns Will Only Grow. In the last decade, the U.S. electric utility industry has spent staggering amounts on pollution control: capital investments for SO_2 emissions control alone were more than $60 billion. The annual costs for air pollution control exceed $10 billion; for solid waste disposal, $1 billion. And these amounts, of course, do not include the additional hundreds of billions of dollars spent to improve nuclear plant safety or in the cancellation of planned nuclear capacity or for other environmental expenditures for non-generation operations.

The past summer with its unprecedented temperatures -- reinforcing a pattern through the 1980s -- has again focused major attention on the environment. Concerns over global warming are reinforcing action to address other areas of environmental concern, including acid rain and ozone depletion.

With the call for increased attention to the environment by both national parties, environmental constraints facing the deployment of new electrical generations will only grow. These concerns will likely involve emphases on higher efficiencies, cleaner fuels, and wise energy use.

Public Power Financing Options Are Being Squeezed. Public power systems finance capital expansion with municipal bonds. Last year public power systems issued $11 billion in bonds. Two recent events, however, are squeezing public power's flexibility to finance expansion through these historically tax-exempt bonds.

In the first event, the use of municipal bonds to acquire facilities of private power companies was limited. A side effect is that existing public power systems are also now limited in co-owning larger generating facilities with a private partner, foreclosing one of the past key avenues used to grow into longer-term capacity requirements.

In the second event, the U.S. Supreme Court ruled that interest on municipal bonds is not constitutionally protected against taxation by the federal government. If state and local governments are not successful in sustaining this tax protection the cost of debt may rise by an estimated 20 to 35%.

Risk and the Importance of Local Control and Self-Generation. For most of public power, risk is compounded by small size. Such risk manifests itself not only in the competition between smaller and larger entities, but in the consequences of smallness itself.

Smaller public power systems have been less able to diversify their resource mix because of prior economies of scale in large generation. Prior diversification strategies of small percentage ownership in multiple projects have now been foreclosed.

As for the risk due to smallness itself, consider the "law of large averages." For a very large utility, loss of a major industrial customer or construction of a major residential subdivision can be absorbed or compensated for elsewhere in the system. Such load changes can have a major impact on a smaller systems, however.

Diversity, flexibility and quick response are the most robust strategies for dealing with risk. Ownership of power supply reduces uncertainty. That is why so many public power systems that do not now generate desire to do so. And for those that do generate, greater diversity through "bite-sized" chunks of new generating capacity is desired.

These desires -- plus the characteristics of community ownership noted in Appendix A of the NOMO -- translate into the importance of self-generation and local control for power supply. Thus, many public powers systems' requirements for new generation can not be measured by incremental growth requirements alone as they are for larger integrated utilities: The replacement of existing bulk power purchases is an important market factor in its own right.

An Emerging Re-Definition of Public Power as Energy Service Providers. As entities owned by the local community, it is appropriate to ask "What is the business of public power?" During the past decades of improving electrical efficiencies, economies of scale, and declining real prices for electricity, public power's business was appropriately defined as keeping rates as reasonably low as possible while providing reliable service.

These objectives remain. But the times are changing. Conserving electricity may be more economical than selling it. And providing double the energy service through combined heat and power production may be more cost-effective and cleaner in terms of overall energy service delivered than generating electricity alone.

Public power rightfully prides itself on the "yardstick" for electric rates it has provided in comparison to private utilities for the past 100 years. A new yardstick is emerging, however. that is, to act as an honest broker for the alternatives that make best economic sense to the local community.

Fuel Cells Promise to Meet These Strategic Requirements. All of the challenges above provide a unique fit with fuel cells. It is for these reasons that APPA and its members issued the "Notice of Market Opportunity for Fuel Cells."

The NOMO is not a request-for-proposals. Rather, the NOMO is intended to identify opportunities for workable and mutually beneficial relationships between public power and prospective manufacturer(s) to promote the early commercialization of fuel cells.

Public power is prepared to take aggressive steps to assist in making fuel cells a commercial reality by the mid-1990s.

The American Public Power Association and many of its members have been active in efforts to promote the development of fuel cells for more than a decade. The kinds of efforts and involvements have varied, from support for continued R&D funding or participation with user groups to tentative commitments for hosting multi-megawatt demonstrations or securing orders for early "market entry" units. Similar steps may be taken as a result of responses to our NOMO.

Public power, however, while a significant potential market, is insufficient alone to assert the "market pull" necessary for commercialization. Thus we view our role as a catalytic one, with the need to involve other potential buyers beyond public power in our ensuing negotiations with manufacturers.

MANUFACTURERS MUST SHARE RISKS AND COSTS

Fuel cells, like other emerging and modular energy technologies such as photovoltaics, will be characterized by great economies of scale in manufacturing. The more that are made, the cheaper they will be.

The non-recurring costs associated with, first, demonstrating the technology, and, then, refining commercial designs and building manufacturing plant, impose substantial first-cost hurdles.

Yet, if initial commercialization is successful, huge profits stand to be made. Furthermore, the first manufacturer to offer a commercially viable fuel cell will gain an immediate 100 percent market share, in turn generating substantial cash flow for continuing technology improvements that will make it very difficult for other prospective manufacturers to enter the market and compete.

APPA thus believes, in recognition of these potential gains and to help ensure that they in fact come about, that prospective fuel cell manufacturers must snare in the risks and costs of technology demonstration and early commercialization.

In our NOMO, we therefore set forth these criteria as requisite expressions of the manufacturers commitment to commercialization:

Acceptable Cost. "Acceptable" cost is extremely difficult to define. This difficulty is due to the unique characteristics of fuel cells, to the possible design trade-offs which may credit to various degrees these characteristics, and to the relative needs and constraints of the potential markets.

Studies by the Electric Power Research Institute (EPRI) indicate that various electric utilities may "credit" fuel cells anywhere from no dollars to a few hundred dollars to a thousand dollars per kilowatt or more over the capital costs for conventional alternatives. From such studies, it is clear that fuel cells may receive initial (and, perhaps, limited) market acceptance at a cost premium. To reach the potential total market, however, where credits may not be applicable, requires costs equivalent to conventional alternatives. Fixed vs. variable cost trade-offs will also occur.

Nonetheless, apart from initial demonstrations of the technology, which APPA understands will be more expensive and can not be compared on commercial grounds, the earliest commercial units should not exceed $1,500 to $2,000/kW in order to be "acceptable." Eventual cost goals should be in the $800 to $1,000/kW range.

Obviously, at the lower end of these cost ranges, the potential market is larger. The challenge in meeting "acceptable" costs appears to be to find innovative pricing alternatives for initial units so as to overcome the vicious cycle inherent in the cost-to-megawatts-built relationship. Finding a solution to this commercialization challenge acceptable to buyers and at least one supplier is the primary objective of APPA's "Notice of Market Opportunity" document.

Commercialization No Later Than the Mid-1990s. In order to justify any near-term actions that public power might take to assist fuel cell development, a responsive manufacturer should be able to present a realistic and orderly plan to achieve commercialization of their technology no later than the mid-1990s. This target is based on APPA's understanding of the time frame for major capacity additions by many public power systems and realistic expectations for commercialization of the technology under an aggressive commitment by manufacturer(s).

Longer-Term Indicators of Corporate Commitment. Public power is interested in a long-term commitment from fuel cell manufacturer(s). Some of these indicators are:

- An expressed commitment for the long-term support of the technology;
- An identification of technical limitations of major plant subsystems in the current design and the commitment to a continuing program of technology improvement;
- A long-term program that includes aggressive cost-reduction goals;
- Tangible commitments to manufacturing plant and capabilities; and
- Corporate commitment to develop a "family" of products in a range of sizes sufficient to meet the diverse characteristics of public power systems.

Willingness to Address "Commercialization" Criteria. The ultimate thrust of any manufacturer's commercialization plan should be to offer potential buyers:

- Standardized plant design, with full scope of supply defined;
- Demonstration of all major plant subsystems in an integrated powerplant at scale, with predetermined acceptance criteria met;
- Utility-grade criteria of reliability, availability and maintainability

(RAM) met;

- Warranted powerplant performance specifications;
- Minimum 25-year powerplant lifetime;
- Quotable fixed capital cost (excluding site, etc.,) and non-consumable O&M costs;
- Warranted availability of spare parts at quotable cost for duration of powerplant lifetime;
- Critical spare parts inventory on-hand with minimum 5-day delivery;
- Tangible manufacturing plant and capability;
- Marketing plans, capability and literature developed; and
- Standard contract offering.

THE "DEMONSTRATION GAP" REQUIRES PUBLIC-PRIVATE PARTNERSHIPS

The federal government has spent billions to research renewable and advanced energy options. But this federal investment stands at risk because the market-scale demonstrations essential to commercial acceptance are not taking place. More importantly, advanced energy options for meeting energy and environmental goals may not be available when needed.

Fuel cells are a particularly acute example of this "demonstration gap." Through 1989, U.S. DOE expenditures on fuel cell R&D are estimated to be $438 million. Perhaps a similar amount has been expended by the private sector, leading to a total of about $900 million.

Yet by FY 1989, Japanese government expenditures on fuel cells exceeded those of the U.S., with Europe quickly closing the gap. This has come on the heels of a disastrous lack of U.S. support for energy technology demonstrations throughout the 1980s.

DOE's distressing request for reduced fuel cell R&D funding is not new. The Reagan Administration consistently opposed adequate fuel cell R&D funding. While Congress has generally restored funds to a significant extent, the uncertainty of consistent funding has harmed the ability of manufacturers to sustain the multiyear commitments necessary for their development efforts. Also, such starts-and-stops in federal support have contributed to the narrowed lead of the United States over its international competitors.

The declines in federal support for fuel cell demonstrations could not have happened at a worse time. Not only has U.S. technological leadership eroded, but the inability of either potential buyers or manufacturers to shoulder the substantial first-cost hurdles associated with needed demonstrations at scale or with early commercialization efforts has led to perceptions of "lack of market interest," as quoted earlier. Yet the problem is not lack of interest, but rather lack of leadership.

The budget deficit dictates a different role for the federal government from what was possible during the heyday of energy funding in the late 1970s. Moreover, many of those earlier programs did not result in the commercial availability and market acceptance of new energy technologies. In part, this failure was due to the lack of user or buyer involvement in the setting of funding priorities or technology definition.

For technologies such as fuel cells, the substantial risks and costs associated with first-of-a-kind energy technology demonstrations at scale requires support from the public sector. Each of the key players -- government, suppliers and market -- is needed, but insufficient alone to secure such demonstrations. Without innovative approaches to this conundrum, the very real prospect is that advances pioneered in the United States will be packaged and sold back to us by foreign competitors, further worsening the nation's trade deficit and causing the loss of excellent export opportunities.

APPA believes that public-private partnerships can and must be forged to address this energy technology "demonstration gap." But to best ensure success, APPA also believes the appropriate role of the federal partner is to help smooth the first-cost hurdles, while leaving the manufacturer-buyer relationship intact. This is the topic of the next section.

A NEW APPROACH IS NEEDED

To realize the biggest bang for a minimal investment of the federal energy R&D dollar requires a balanced approach that is responsive to national needs, technically achievable at acceptable cost, and has good prospects for market acceptance. APPA suggests these points in a plan to realize these objectives:

Emphasize Opportunities That Meet a Balance of National and Market Goals. A set of criteria is essential for evaluating potential energy options. At minimum, such criteria should include:

- Large domestic market potential and market interest;
- Superior environmental performance, including low carbon dioxide emissions;
- Higher energy efficiency or prospects for higher capacity utilization in comparison with conventional alternatives;
- Smaller-scale and modular design, leading to quicker implementation and lower risks;
- Current U.S. technological leadership, or reasonable potential to assume such leadership;
- Lessened reliance on foreign energy supply; and
- Strong export potential.

These criteria may seemingly pose an impossibly high standard for advanced energy options. Yet APPA believes there are opportunities that meet these criteria. And, in instances where promising technologies fail some of these criteria, priority should be given to applied research that will cause these criteria to be met.

Conduct Market Assessments. Dollars spent on developing energy technologies that fulfill only limited "niche" markets or that due to operational or performance characteristics are unlikely to meet market acceptance are poorly spent dollars. Small amounts of federal seed money, matched with the bulk of money from the markets themselves, should be used to conduct assessments of market potential for promising options. These studies would be best managed by industry groups or associations. Competitive grant procurements would surface those industries most interested and capable of conducting such studies.

Where markets are relatively small or interest weak, the technologies under consideration should be dropped.

Use DOE's Existing Framework for "Cooperative R&D Ventures". For opportunities that meet national goals and market acceptance, a framework already exists within DOE for participating in cooperative energy R&D ventures. (See "Cooperative R&D Ventures: An Opportunity for Leveraged Research in Fossil Energy," DOE/FE-0079, February 1987.) Congress has yet to appropriate funds to implement this initiative, and may want to suggest some criteria and procedures of its own, but the basic mechanism is in place and is sound.

Require Market and Supplier Co-funding. If first-cost hurdles associated with energy demonstrations at scale can be successfully overcome, the market will benefit by having an improved alternative to conventional approaches, and the supplier will benefit by demonstrating performance to the markets which are generally adverse to technical risk. The prospects for these benefits should be acknowledged by substantial cost-sharing by both the market and the supplier in these demonstrations.

Previous DOE cost-sharing programs, such as the Clean Coal Technology Initiative, have required at least 50 percent co-funding by the non-federal participants. A willingness to assume much larger co-funding by the markets and supplier should be encouraged as a tangible expression of commercialization potential.

Furthermore, consortia proposals by potential markets should be required, since they reflect a broad-based market need. Assurance of market interest may encourage suppliers to "forward price" their subsequent market-entry efforts, thus promoting commercialization.

Project Management Should Be the Responsibility of the Market. Only the market as potential users can gauge the performance and success of a demonstration. While access to all project information and participation in the management team should be provided to the federal participants, substantial flexibility and project control should be granted to the private participants. Steps to minimize red tape associated with federal procurement and contracting should be lessened.

Technology Transfer Should Be Incorporated from the Beginning. Not all market entities will be willing to participate during a demonstration phase, yet, after a successful demonstration, may become eager and important buyers. Mechanisms to transfer the experience gained during demonstrations to this larger group is essential. Technology transfer should be a required component of any joint venture receiving federal support.

In summary, if a modest plan along these lines were implemented and funded, APPA believes a resounding response from all energy-related markets would be forthcoming.

CONCLUSIONS AND RECOMMENDATIONS

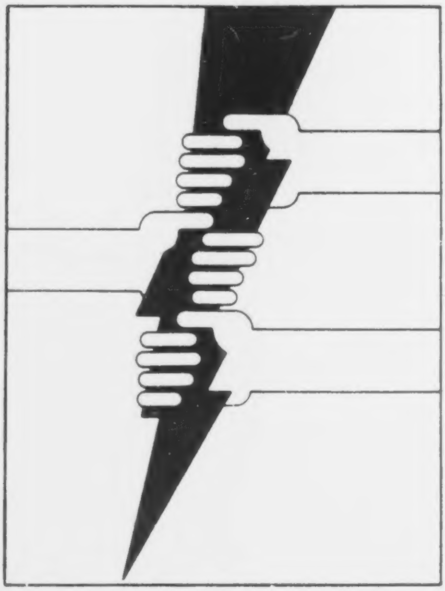
APPA obviously believes in the important contribution fuel cells can provide and in the large size of the potential market. For those reasons alone, APPA urges FY 1990 DOE funding at least equivalent to FY 1989 levels, if not higher.

Beyond 1990, however, the thrust of our comments suggests an alternative approach. Retain the current approach of line item appropriations for basic and applied energy R&D, but create a new fund for cooperative demonstration ventures for all advanced energy technologies. Provide sufficient time for cooperative ventures between manufacturers and buyer's (market) consortium to develop, and then let each of these ventures compete for available funds.

The basic outlines of this approach are suggested in the previous section.

APPA believes this approach holds the greatest prospect for limited federal energy dollars to achieve the largest tangible results. It is fair and market-driven. And, it acknowledges the nation's critical energy technology "demonstration gap."

NOTICE OF MARKET OPPORTUNITY FOR FUEL CELLS



Issued by the

American Public Power Association
2301 M Street, NW
Washington, DC 20037

October 1988

Responses from suppliers are requested by February 1, 1989

NOTICE OF MARKET OPPORTUNITY FOR FUEL CELLS

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Preparation of this Notice of Market Opportunity has been supported by APPA's DEED (Demonstration of Energy-Efficient Developments) research program. Appreciation is extended to the Electric Power Research Institute and Technology Transition Corporation for their assistance.

SUMMARY

The American Public Power Association (APPA), on behalf of the 2,200 public power systems in the United States, invites prospective manufacturers of megawatt-scale fuel cells to respond to this "Notice of Market Opportunity for Fuel Cells" (NOMO). Through this NOMO, APPA and its members desire to encourage and accelerate the commercial readiness and availability of fuel cells no later than the mid-1990s.

APPA and its members are offering to establish a collaborative relationship with one or more manufacturers to achieve this purpose. This unprecedented invitation results from compelling reasons:

- Public power systems in the United States desire technologies for generating electricity that are efficient, cost-effective, smaller-scale and meet standards of technical and environmental performance and of public acceptance sufficient for siting near electrical loads;

- Public power systems are an important market for new generation, with combined annual retail sales of about 325,000 GWh and 89,000 MW of currently installed capacity. Changes taking place within the U.S. electric utility industry, moreover, may increase the importance of self-generation for public power systems;

- Public power has observed that initial efforts to commercialize fuel cells within electric utilities have emphasized where the size of the absolute market is largest. Yet the U.S. market for electric supply is becoming increasingly fragmented, with fuel cells fulfilling a "niche" role, albeit an important one. The needs and requirements of many public power systems may be similar to those of large, urban utilities and many of the emerging independent power producers;

- Public power systems -- though diverse in their needs for new generation -- have concluded that fuel cells address the dilemma of a tightening "power supply vise": one jaw of that vise being limitations on transmission access or building new transmission lines; the other jaw being the increased environmental and financial constraints facing conventional generation; and

- Public power's experience with a prior initiative to demonstrate multi-megawatt fuel cells offered a pointed lesson in the difficulty in commercializing this technology. High initial costs and a lack of demonstrated performance in utility-grade powerplants will require innovative and collaborative relationships between the suppliers and the markets (and, perhaps, others). Over the long-term, fuel cells promise continued efficiency improvements and cost reductions due to mass production.

This NOMO is therefore public power's attempt to encourage fuel cell commercialization and to influence product design sufficiently to meet public power's needs.

This NOMO is *not* a request-for-proposals. Rather, the NOMO is meant to identify opportunities for workable and mutually beneficial relationships between public power and prospective manufacturer(s) to promote early commercialization of fuel cells.

Public power is prepared to take aggressive steps to assist in making fuel cells a commercial reality by the mid-1990s. But the exact nature of those steps and assistance will depend on the individual responses from manufacturers to this NOMO, and the manner in which any ensuing relationships unfold.

Only manufacturers that can realistically respond to the challenge of providing a commercial product by the mid-1990s need respond in detail to this NOMO. We seek responses from capable manufacturers that will:

1) describe their fuel cell designs, technology status, and operating experiences;

2) offer realistic plans for bringing their technology to commercialization;

3) project capital and operating costs;

4) identify desired means of assistance to help promote early commercialization; and

5) provide ideas on how to work collaboratively with public power to promote these objectives.

The main body of this NOMO describes our purposes and objectives, why public power is interested in fuel cells and our efforts in support of the technology, our preliminary assessment of the public power market for fuel cells, and a recommended framework for manufacturers' responses to this NOMO. Quantitative material further describing the public power market and other supporting material is appended to the main body of the NOMO.

APPA and its members sincerely hope that prospective manufacturers of fuel cells perceive the opportunity for mutual benefit represented by this NOMO and respond to it. Responses are requested to be submitted to APPA no later than February 1, 1989.

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I. PURPOSE AND OBJECTIVES

The American Public Power Association (APPA) and many of its members have been active in efforts to promote the development of fuel cells for more than a decade. The kinds of efforts and involvements have varied, from support for continued R&D funding or participation with user groups to tentative commitments for hosting multi-megawatt demonstrations or securing orders for early "market entry" units.

Throughout this period, the commercial availability of fuel cell powerplants has always been "just around the corner." Most recently, the failure of an effort to demonstrate three or four 11-MW powerplants that was being spearheaded by the Electric Power Research Institute has alarmed the public power community and offered some pointed lessons.

This "Notice of Market of Opportunity for Fuel Cells" (NOMO) is a result of those lessons. The NOMO signals public power's willingness to assume a more active role in breaking the impasse that is frustrating early commercialization of the technology.

A general description of public power and its relation to the rest of the U.S. electric utility industry is offered in Appendix A. A quantitative description of public power is offered in Appendix B.

Statement of Purpose

The purpose of this "Notice of Market Opportunity" is threefold:

- Firstly, to invite responses from prospective manufacturers of fuel cells to begin a process of discussions and collaborations with public power that will help promote the commercial availability of megawatt-scale fuel cells no later than the mid-1990s;
- Secondly, to inform various audiences about the importance of the public power market for generation, and the applications, requirements and decision factors that may guide its choices for new capacity additions; and
- Thirdly, through this information and collaboration, to influence prospective manufacturers' product designs and commercialization strategies so as to achieve maximum acceptance by the public power market.

The common thread in these statements of purpose is the building of a partnership between the market and supplier(s).

Why This Notice is Limited to Fuel Cells

Many public power systems in the United States desire technologies for generating electricity that are efficient, cost-effective, smaller-scale and meet standards of technical and environmental performance and of public acceptance sufficient for siting near electrical loads. More specific information on these objectives is offered on pages 29 - 32.

Other technologies besides fuel cells may be able in part or in whole to meet these performance objectives. Yet longer-term, fuel cells may offer unparalleled advantages. First, factory fabrication and mass (and automated) production promise significant cost reductions. And second, fuel cell efficiencies are at the bottom of the learning curve for efficiency improvements. As experience is gained and basic science improves, fuel cell efficiencies should climb higher. Other technologies based on Carnot cycles with their inherent thermodynamic limitations are already near the top of their learning curve, and can only offer marginal efficiency improvements at best.

Of course, public power systems own many types of generation and will continue to purchase a diverse mix of resources. APPA hopes manufacturers of non-fuel cell technologies can also gain benefit from this document. This NOMO by no means implies that fuel cells are the only serious option being considered by individual utilities (nor that public power systems are solely interested in *megawatt-scale* fuel cells). Yet, because fuel cells are a *fundamentally* new technology that have an initial hurdle to overcome before mass production drives down costs (especially at larger scale), public power systems can -- and perhaps will need to -- play an innovative and catalytic role in order for fuel cells to become commercially available.

For these reasons, APPA's members adopted a policy resolution in June 1988 supporting the commercialization of fuel cells (see Appendix C). This policy provides the rationale for targeting fuel cells in this NOMO. Indeed, the NOMO itself is an outgrowth of the directives set forth in that resolution.

One final note: Phosphoric acid fuel cells (PAFC) appear the closest to commercial reality in megawatt-scale size ranges. As a result, some of the performance objectives and criteria offered in his NOMO reflect that orientation. However, prospective manufacturers of solid oxide fuel cells (SOFCs) or molten carbonate fuel cells (MCFCs) that believe their product offerings will meet the objectives laid forth in this NOMO are also strongly encouraged to respond. In considering responses to this NOMO, APPA members will take into account any differences due to the type of fuel cell proposed.

Why is Public Power Interested in Fuel Cells?

The unique benefits promised by fuel cells provide a strategic answer to many of the challenges facing public power. This section summarizes those benefits and challenges.

The unique benefits of fuel cells. Fuel cells promise unique benefits to public power communities. They are clean, quiet, siteable in urban areas, and can be constructed in months rather than years. Their modular design may act to increase reliability and lessen risk by allowing "building block" expansion, and shorter planning horizons. Unique operating capabilities include responsive load following, rapid ramp rates, power factor improvement (reactive power compensation), and system protection. Electrical efficiencies are high with excellent prospects for further improvement. And, they are well-suited for cogeneration.

Appendix D is a more detailed description of APPA's understanding of these unique benefits.

Evolving trends in the electric utility industry. The decade of the 1980s has been a period when the concepts of "deregulation" and "competition" moved out of academic classrooms to political back rooms. Trucks, phones, banks, airlines, and most recently, natural gas have become deregulated. Over the last year, serious consideration has been given in the U.S. Federal Energy Regulatory Commission (FERC) to deregulate electric utilities through administrative action.

Currently pending are FERC proposals apparently intended to do three things: (a) make it clear that electric utilities do not have to buy capacity they don't need or to pay prices which are unrealistic for electricity produced by cogenerators and small power producers; (b) encourage use of competitive bidding in the acquisition of *any* power purchased; and (c) relieve "independent power producers" -- non-utility generators -- and private power companies from FERC regulation under certain conditions.

If such proposals become law, there are numerous ramifications in their details that could place many public power systems at a competitive disadvantage, especially those that now depend upon a well-regulated bulk power supply market. Even if these proposals do not become law, they are harbingers of many other trends within the industry.

For example, increased competition is occurring in the power industry as witnessed by: the growth of third-party cogenerators; mergers and consolidations by private utilities; attempts by private utilities to buy out public power systems; attacks on the historical methods by which power from federal dams is allocated or licenses for new or existing dams are granted; and competition between utilities for new industrial customers or annexation of service territories. As the regulatory compact between state utility commissions and their regulated utilities changes, new experiments in market-based bidding programs, on the one hand, and more proscriptive least-cost planning requirements, on the other, are becoming prevalent.

Competition in the electric utility industry is here today. And all signs point to increased competition in the future.

Transmission access and new lines are a major uncertainty. Three-quarters of public power systems have no generation. Their flexibility in purchasing the wholesale power they distribute is critically dependent on access to transmission. Yet public power systems currently own fewer than 10 % of the U.S. electric transmission system. Access to transmission by the large majority of public power systems depends on their ability to negotiate contracts on their own or through a joint action agency, or to secure it through lengthy and expensive judicial proceedings. More than 80 % of the nation's transmission circuit miles are owned by about 180 private utilities.

The importance of the bulk power market has grown tremendously in recent years. Today, at least 30 % of total power sales in the United States occurs through the bulk (transmission-dependent) market. Individual public power systems depend on purchased power for *almost 85 %* of their total sales to ultimate customers.

Yet if access is limited, or the building of new lines is constrained due to questions of public acceptance, economies to be gained in the bulk power market are foreclosed. And, should generation be further deregulated without ensuring equitable access to transmission, the competitive squeeze for many smaller utilities could be fatal.

Self-generation thus becomes an important option in its own right and as a bargaining lever to secure access to transmission controlled by private utilities.

Environmental concerns will only grow. In the last decade, the U.S. electric utility industry has spent staggering amounts on pollution control: capital investments for SO_2 emissions control alone were more than $60 billion. The annual costs for air pollution control exceed $10 billion; for solid waste disposal, $1 billion. And these amounts, of course, do not include the additional hundreds of billions of dollars spent to improve nuclear plant safety or in the cancellation of planned nuclear capacity or for other environmental expenditures for non-generation operations.

The past summer with its unprecedented temperatures -- reinforcing a pattern through the 1980s -- has again focused major attention on the environment. Concerns over global warming are reinforcing action to address other areas of environmental concern, including acid rain and ozone depletion.

With the call for increased attention to the environment by both national parties, environmental constraints facing the deployment of new electrical generation will only grow. These concerns will likely involve emphases on higher efficiencies, cleaner fuels, and wise energy use.

Public power financing options are being squeezed. Public power systems finance capital expansion with municipal bonds. Last year public power systems issued $11 billion in bonds. Two recent events, however, are squeezing public power's flexibility to finance expansion through these historically tax-exempt bonds.

In the first event last year, the use of municipal bonds to acquire facilities of private power companies was limited. A side effect is that existing public power systems are also now limited in co-owning larger generating facilities with a private partner, foreclosing one of the past key avenues used to grow into longer-term capacity requirements.

In the second event, this year, the U.S. Supreme Court ruled that interest on municipal bonds is not constitutionally protected against taxation by the federal government. If state and local governments are not successful in sustaining this tax protection the cost of debt may rise by an estimated 28 to 35 %.

Risk and the importance of local control and self-generation. For most of public power, risk is compounded by small size. Such risk manifests itself not only in the competition between smaller and larger entities, but in the consequences of smallness itself.

Smaller public power systems have been less able to diversify their resource mix because of prior economies of scale in large generation. Prior diversification strategies of small percentage ownership in multiple projects have now been foreclosed.

As for the risk due to smallness itself, consider the "law of large averages." For a very large utility, loss of a major industrial customer or construction of a major residential subdivision can be absorbed or compensated for elsewhere in the system. Such load changes can have a major impact on a smaller system, however.

Diversity, flexibility and quick response are the most robust strategies for dealing with risk. Ownership of power supply reduces uncertainty. That is why so many public power systems that do not now generate desire to do so. And for those that do generate, greater diversity through "bite-sized" chunks of new generating capacity is desired.

These desires -- plus the characteristics of community ownership noted in Appendix A -- translate into the importance of self-generation and local control for power supply. Thus, many public powers systems' requirements for new generation can not be measured by incremental growth requirements alone as they are for larger integrated utilities: The *replacement* of existing bulk power purchases is an important market factor in its own right.

An emerging re-definition of public power as energy service providers. As entities owned by the local community, it is appropriate to ask "What is the business of public power?" During the past decades of improving electrical efficiencies, economies of scale, and declining real prices for electricity, public power's business was appropriately defined as keeping rates as reasonably low as possible while providing reliable service.

These objectives remain. But the times are changing. Conserving electricity may be more economical than selling it. And providing double the energy service through combined heat and power production may be more cost-effective and cleaner in terms of overall energy service delivered than generating electricity alone.

Public power rightfully prides itself on the "yardstick" for electric rates it has provided in comparison to private utilities for the past 100 years. A new yardstick is emerging, however. That is, to act as an honest broker for the alternatives that make best economic sense to the local community.

Fuel cells promise to meet these strategic requirements. All of the challenges above provide a unique fit with fuel cells. It is for these reasons that APPA and its members support the technology's commercialization.

What the NOMO Is and Is Not

This NOMO, firstly, is *not* a request-for-proposals. It *is* an invitation to prospective manufacturers to begin a dialogue with public power that may lead to collaborative arrangements of mutual benefit. Responses to this NOMO are not meant to be final and will not be evaluated as such.

This NOMO, secondly, is *not* a general statement of the future generation needs for all of public power. Conventional baseload generation, peaking plants, and power purchases, for example, will continue to be dominant for many years to come. The NOMO is, however, a description of the needs and market for the very important strategic niche that public power systems foresee for fuel cells.

This NOMO, thirdly, is *not* a proscriptive set of technical specifications. It *is* a description of desired performance, cost and commercialization objectives. APPA believes that only the manufacturer is best able to make design and cost trade-offs. This document thus does not specify requirements for a certain size powerplant or certain operating modes. Rather, the attempt is to provide the best market information available whereby responsive alternatives that meet manufacturing and design constraints can be offered.

This NOMO, fourthly, *is* an expression of public power's interest in fuel cells. If, however, our efforts can help catalyze a workable commercialization plan, APPA and its members would welcome the involvement of third parties. These parties could be, for example, either non-public power electric utilities or generators as participants, or other manufacturers or suppliers as co-sponsors.

APPA and its member reviewers, fifthly, do *not* guarantee that a collaborative dialogue will be begun with any respondent to this NOMO. Conceivably all of the responses may be seen as insufficient to meet public power's objectives and therefore not to warrant further discussions; or, the role of public power itself may not be needed in helping to promote commercial readiness. On the other hand, APPA and its member reviewers reserve the right to begin discussions leading to a collaborative relationship with more than one manufacturer, should the responses so warrant.

Only manufacturers capable of providing a commercial product by the mid-1990s should respond in detail to this NOMO. While public power maintains a keen interest in advanced fuel cell concepts and longer-term R&D, such interest is not the purpose of this Notice.

Lastly, APPA seeks to have this NOMO facilitate the exploration of alternatives. Responses from manufacturers that lay out multiple options or suggest ideas not already surfaced in this NOMO are welcomed and encouraged.

What Is "Commercialization?"

Since the ultimate objective of this NOMO is the development of megawatt-scale fuel cell powerplants as a commercially viable alternative, public power offers these criteria for what it considers to be "commercialization:"

- Standardized plant design, with full scope of supply defined;
- Demonstration of all major plant subsystems in an integrated powerplant at scale, with pre-determined acceptance criteria met;
- Utility-grade criteria of reliability, availability and maintainability (RAM) met;
- Warranted powerplant performance specifications;
- Minimum 25-year powerplant lifetime;
- Quotable fixed capital cost (excluding site, etc.,) and non-consumable O&M costs;
- Warranted availability of spare parts at quotable cost for duration of powerplant lifetime;
- Critical spare parts inventory on-hand with minimum 5-day delivery;
- Tangible manufacturing plant and capability;
- Marketing plans, capability and literature developed; and
- Standard contract offering.

Any discussion with prospective manufacturers will begin with a set of agreed-upon objectives and commercialization criteria.

Performance Objectives

The unique benefits of fuel cells, noted above, are a key factor in public power's interest in fuel cells. The specific performance objectives leading to this interest are:

- ***High efficiency*** -- heat rates for the first commercial fuel cells should be at least comparable to the best conventional alternatives in their applicable size ranges. Steady improvement in these efficiencies would be expected as experience is gained with the technology. In addition, to provide maximum flexibility in unit dispatch, and therefore potential applicability, high efficiencies at part load are also critical;
- ***Superior environmental performance*** -- substantial improvements in emission rates, discharges and waste production over well-controlled conventional generation will be necessary if fuel cells are to be accepted for near-load applications. The 1991 and 1994 air standards for Southern California will be a performance benchmark for fuel cells;
- ***High reliability and availability*** -- all utility-grade generation must meet such objectives. However, since it is possible that much of the potential fuel cell capacity within public power would occur within systems that presently do not

generate or have a limited resource mix, exceptional reliability and availability will be necessary for maximum market acceptance;

- ***Modular size*** -- modularity in design leads to incremental capacity additions more closely matched to growth, more standardized construction leading to easier maintainability and shared inventory, and hence to lower costs and risks. Another important objective of modularity, however, is the potential for "ganging" units incrementally over time at a given plant site. This objective is important for public power systems with a limited number of sites or which desire lower long-term costs due to shared balance of plant;

- ***Short lead times*** -- the modularity noted above should lead to short lead times if permitting is straightforward and field construction times short. This objective is critical to lessen uncertainties inherent in planning for future load growth and to maintain optimum power output for invested fixed costs;

- ***Cogeneration potential*** -- since initial capital costs for fuel cells are likely to be higher than those for competing alternatives, credits for thermal sales may be the critical factor in early purchases. Flexible sizing for thermal or electrical loads, plus thermal output suitable for a wide range of cogeneration applications are therefore an essential objective;

- ***Automated and unattended operation*** -- automated start-up, shutdown and emergency operation make for a more forgiving technology. Combined with the potential for unattended operation, the need for larger and more sophisticated operating staffs can be lessened. For smaller public power systems, meeting this objective may be the *key* factor in their market acceptance; and

- ***Fuel flexibility*** -- single fuel capabilities increase risk due to the possibility of curtailments or fuel price increases. Single-fuel capabilities may also limit regional applicability of the technology. The optimal objective is at least for low retrofit costs to use fuels other than natural gas (such as light distillates). Many of the current smaller-scale generators in public power currently have dual-fuel capabilities.

Trade-offs between these objectives obviously occur and each has its own cost implication. High reliability and ease of operation are favored, for example, over such costly additions as unnecessarily quick response times. Nevertheless, these performance objectives constitute what would be an optimal generating technology for many public power systems. How these objectives might be defined through a set of detailed performance specifications is outlined in Section IV.

Combined, these performance objectives translate into a technology suitable for in-town generation near load centers. Local control is thus maintained over future power supply and potential constraints to transmission access or other limitations are overcome. Of course, siting near loads means siting near people, with the obvious need to meet standards of public and community acceptance becoming paramount.

Additional information on fuel cell characteristics of interest is provided in Appendix F.

Commercialization Objectives

In addition to performance, public power has three other objectives that will guide its degree of involvement in helping to bring fuel cells to commercial reality: 1) acceptable cost; 2) the manufacturer's ability to commercialize the technology no later than the mid-1990s; and 3) the commitment of the manufacturer to the longer-term development and support of the technology.

It is essential to realize that public power has no interest in demonstrating the viability of fuel cell powerplants for the sake of demonstration alone. As discussed in Section III, *public power is prepared to play a variety of roles in demonstrating fuel cells, but only as an essential step toward successful commercialization.* Many public power systems desire to purchase fuel cell powerplants. For these purchases to occur, technical viability and readiness is only the first criterion that must be met.

Acceptable Cost. "Acceptable" cost is extremely difficult to define. This difficulty is due both to the unique characteristics of fuel cells (and to the design trade-offs which may credit to various degrees these characteristics) and to the relative needs and constraints of the potential market.

Studies by the Electric Power Research Institute (EPRI) indicate that various electric utilities may "credit" fuel cells anywhere from no dollars to a few hundred dollars to a thousand dollars per kilowatt or more over the capital costs for conventional alternatives. From such studies, it is clear that fuel cells may receive initial (and, perhaps, limited) market acceptance at a cost premium. To reach the potential total market, however, where credits may not be applicable, requires costs equivalent to conventional alternatives. Fixed vs. variable cost trade-offs will also occur.

Nonetheless, apart from initial demonstrations of the technology, which APPA understands will be more expensive and can not be compared on commercial grounds, the earliest commercial units should not exceed $1,500 to $2,000/kW in order to be "acceptable." Eventual cost goals should be in the $800 to $1,000/kW range.

Obviously, at the lower end of these cost ranges, the potential market is larger. The challenge in meeting "acceptable" costs appears to be to find innovative pricing alternatives for initial units so as to overcome the vicious cycle inherent in the cost-to-megawatts-built relationship. *Finding a solution to this commercialization challenge acceptable to buyers and at least one supplier is the primary objective of this "Notice of Market Opportunity" document.*

Commercialization no later than the mid-1990s. In order to justify any near-term actions that public power might take to assist fuel cell development (see Section III), a responsive manufacturer should be able to present a realistic and orderly plan to achieve commercialization of their technology no later than the mid-1990s. This target is based on APPA's understanding of the time frame for major capacity additions by many public power systems and realistic expectations for commercialization of the technology under an aggressive commitment by manufacturer(s). Any shortening of this time frame would receive due credit in our evaluation of responses to this NOMO invitation.

Longer-term indicators of corporate commitment. Public power is interested in a long-term commitment from fuel cell manufacturer(s). Other objectives, then, which will figure into APPA and its members' evaluation of this NOMO invitation are:

- An expressed commitment for the long-term support of the technology (see Section IV);
- An identification of technical limitations of major plant subsystems in the current design and the commitment to a continuing program of technology improvement;
- A long-term program that includes aggressive cost-reduction goals;
- Tangible commitments to manufacturing plant and capabilities; and
- Corporate commitment to develop a "family" of products in a range of sizes sufficient to meet the diverse characteristics of public power systems.

These objectives, as translated into the suggested framework in Section IV for responding to this NOMO, set forth APPA's criteria for considering responses.

II. THE PUBLIC POWER MARKET FOR NEW GENERATION

This section, supported by Appendixes A, B, E, and F previews APPA's own assessment of the public power market for fuel cells and new generation. This market assessment, not yet complete, will be the result of a year-long effort, and numerous interviews with selected public power systems, special surveys, focus groups, collection of new secondary data, and the analysis of voluminous APPA statistics and data.

A General Comment on the U.S. Electric Utility Market

Public power has frequently been a market that is overlooked by the manufacturers of new technology. In part, this oversight is due to emphasis on the larger private utilities that comprise most of the market for much electric utility equipment. Public power is made up of more than 2000 separate utilities that represent about 15% of the industry, while about 200 private utilities represent about 75% of the industry. Yet, the U.S. market for electricity supply is becoming increasingly fragmented.

Market segmentation is characteristic of most mature markets. Manufacturers of pick-up trucks, for example, recognize this fact. Fifteen years ago, there was only one market -- the standard 3/4-ton pick-up (with or without gun rack). Today, at least sixteen different markets for pick-ups are recognized, from the traditional to the sport to the utility market. Pick-up trucks are also the fastest growing segment of the consumer vehicle market.

Similar segmentation is possible in the electric generation market. The marked increase in new capacity additions since 1980 due to the cogeneration market is the first concrete signal of this segmentation. Given responsive technology and designs, further segmentation is sure to follow.

The needs and requirements of many public power systems may be similar to those of large, urban utilities and many of the emerging independent power producers.

Market Study Objectives

APPA initiated its assessment of the public power market for fuel cell power plants in 1987 because it needed to know certain things to proceed with the demonstration project then in the planning stage. Knowledge of the size of the market would have been useful to a manufacturer considering a market entry strategy, and knowledge of the market requirements would have been useful to APPA as it planned a demonstration intended to benefit the widest possible segment of its membership. Although the planned demonstration did not proceed, current efforts, including this NOMO, still require good market information.

The objectives of APPA's study of the fuel cell market are as follow:

1) To quantify the characteristics of public power systems that may impact fuel cell purchases;

2) To characterize the decision-making in public power utilities, and by city councils that will impact the purchase of fuel cell power plants;

3) To identify the fuel cell operating characteristics and the sizes of interest to public power systems; and

4) To characterize and quantify the public power fuel cell market.

Study Approach

Separate meetings with about a half dozen public power systems were held initially to help develop a profile for public power interest in fuel cells that would guide the conduct of the market study. From this initial scoping came a study plan with the following elements:

1) A workshop at George Mason University, Center for Interactive Management, to characterize public power decision-making as it may affect the purchase of fuel cell power plants;

2) Responses of 200 municipal utilities to a questionnaire specifically seeking information for this market study;

3) Development of a public power database on the 2000+ systems, joint action agencies and other wholesale suppliers; and

4) Screening and analysis of the data.

Planning for the public power fuel cell demonstration has yielded some information useful to developing hypotheses and preliminary conclusions. One utility, the potential host of the demonstration, revealed much about its interest, its limitations and factors that were influencing its actions. Approximately six other systems had interest enough to be considered potential hosts and to consider possible high-cost early unit purchases. Their various reasons for significant participation in the demonstration and early market efforts shed additional light on the characteristics of the fuel cell market. Then, at a less-detailed level, approximately 20 additional systems had indicated interest in supporting the demonstrations due to their longer-term interests.

Profile of Public Power Systems

Public power represents 14% of the U.S. electric utility industry measured in kilowatt hour sales to ultimate customers, and 12.5% of the industry in terms of installed generating capacity. The public power sector of the industry is made up of about 1950 individual municipal systems, 60 joint action agencies which supply groups of member systems, and other wholesale suppliers. Appendices A and B address the diversity of public power and present a profile of this segment of the industry as compared to significant industry averages and totals.

Certain data profiling public power should be useful to any respondent to this NOMO. For example, here are some salient characteristics of this market:

- Public power is growing at a faster rate than the industry as a whole (4% vs. 2.1% growth in kWh sales to ultimate customers);
- Public power retail rates are often lower than surrounding private and cooperative utilities (an average of 35% lower than the industry as a whole);
- Purchased power comprises 78% of the energy sales to ultimate customers;
- The top 20 municipal systems represent about 37% of the retail energy (kWh) sales of public power systems;
- Three-quarters of the systems are above 10 MW in size, and about 150 systems have peak loads in excess of 100 MW;
- Public power has 89,000 MW of installed capacity today; and
- Approximately 15% of the energy purchased by public power systems is supplied by joint action agencies. About 900 systems are members of joint action agencies.

Public Power Structure

The public power segment of the U.S. electric utility industry is made up of about 1950 individual systems that sell power within the boundaries of cities, small and large, and so-called public utility districts (located principally in Nebraska and the Pacific Northwest). The largest system is owned by the City of Los Angeles with a load of 4750 MW and the smallest have peak loads less than one MW.

Power supply for the smaller systems is usually purchased from a neighboring private or cooperative utility on a rate schedule that may include both a firm contract for power, to which both the seller and buyer are committed, and "partial requirements" or varying power supply which may fluctuate as load and other factors vary. Many public power systems supply some of their own power, for instance, with peaking turbines or diesel engines to reduce the higher cost peak load purchases.

The municipal utility is managed by a utility staff, with oversight by an elected city council. As entities of a political subdivision, the management of a public power utility is likely to be influenced by citizen, political, and technical considerations, as well as economic factors. Many public power systems have responsibility for more than electric sales, including gas, water, sewage, and even cable TV.

Joint action agencies, such as the Municipal Electric Authority of Georgia, have been created in many regions of the country to allow smaller public power systems to collectively meet power supply needs. A typical joint action agency might represent 5 to 25 systems, in part or all of a state and have a peak load of several hundred megawatts. They are large enough to build their own generation, and many do. They usually do not own the transmission system that connects their widely dispersed membership. As organizations formed and supported by individual member utilities, joint action agency management is more likely to be influenced by economic and risk management (and independence) factors, with oversight by a "utility-knowledgeable" board.

Public Power Decision-Making

A workshop for APPA was conducted by George Mason University, Center for Interactive Management, in Fairfax, Virginia, to explore factors that would impact a fuel cell market penetration strategy. The two-day session involved invited public power guests with an interest in their own electricity generation. The objectives were to identify and set priorities among factors influencing decisions regarding self-generation and to identify barriers inhibiting the purchase of self-generation technologies.

The results of this workshop revealed decision factors as shown in Figure 1. The most important decision factors appear on the left. Several expected utility factors emerged as important:

- Financial and cost considerations;
- Impact of rates to retail customers; and
- Reliability.

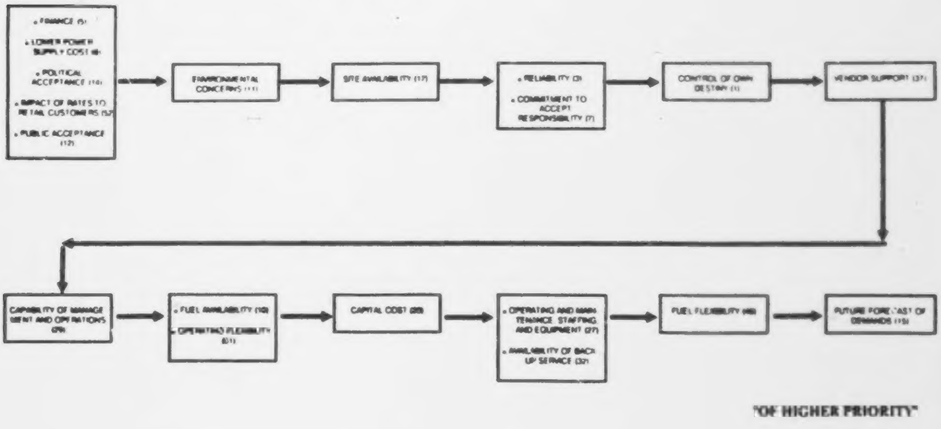

• FINANCE (5)
• LOWER POWER SUPPLY COST
• POLITICAL ACCEPTANCE
• IMPACT OF RATES TO RETAIL CUSTOMERS
• PUBLIC ACCEPTANCE (12)
ENVIRONMENTAL CONCERNS
SITE AVAILABILITY (17)
• RELIABILITY (3)
• COMMITMENT TO ACCEPT RESPONSIBILITY (7)
CONTROL OF OWN DESTINY (1)
VENDOR SUPPORT (37)
CAPABILITY OF MANAGEMENT AND OPERATIONS
• FUEL AVAILABILITY
• OPERATING FLEXIBILITY (31)
CAPITAL COST
• OPERATING AND MAINTENANCE STAFFING AND EQUIPMENT (27)
• AVAILABILITY OF BACK UP SERVICE
FUEL FLEXIBILITY
FUTURE FORECAST OF DEMANDS (15)
"OF HIGHER PRIORITY"

Figure 1. Priority Structure of Decision Factors to Self-Generate

But, several factors that are possibly more important to public power systems than to other utilities also emerged:

- Political and public acceptance;
- Environmental concerns;
- Site availability; and
- Control of own destiny.

Barriers to utilizing a technology were identified and priorities set for a joint action agency case and a representation of the results are presented in Figure 2. The most fundamental barriers appear on the left because they increase the severity of all the barriers to the right.

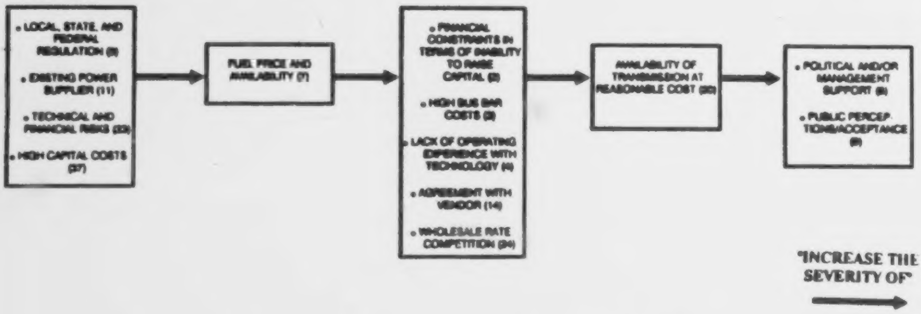

• LOCAL, STATE, AND FEDERAL REGULATION (9)
• EXISTING POWER SUPPLIER (11)
• TECHNICAL AND FINANCIAL RISKS (22)
• HIGH CAPITAL COSTS (27)
FUEL PRICE AND AVAILABILITY (7)
• FINANCIAL CONSTRAINTS IN TERMS OF INABILITY TO RAISE CAPITAL (2)
• HIGH BUS BAR COSTS (3)
• LACK OF OPERATING EXPERIENCE WITH TECHNOLOGY (4)
• AGREEMENT WITH VENDOR (14)
• WHOLESALE RATE COMPETITION (24)
AVAILABILITY OF TRANSMISSION AT REASONABLE COST (20)
• POLITICAL AND/OR MANAGEMENT SUPPORT (6)
• PUBLIC PERCEPTIONS/ACCEPTANCE (8)
"INCREASE THE SEVERITY OF"

Figure 2. Barriers for a Joint Action Agency

Figure 3 combines the decision factors and barriers into a summary graphic, with the key nexus of "public acceptance" providing the linkage. The fuel cells superior environmental characteristics and technical flexibility, which results from modularity, short construction time and efficiency at most operating conditions, suggest it is well suited to the unusual demands of the public power generation market.

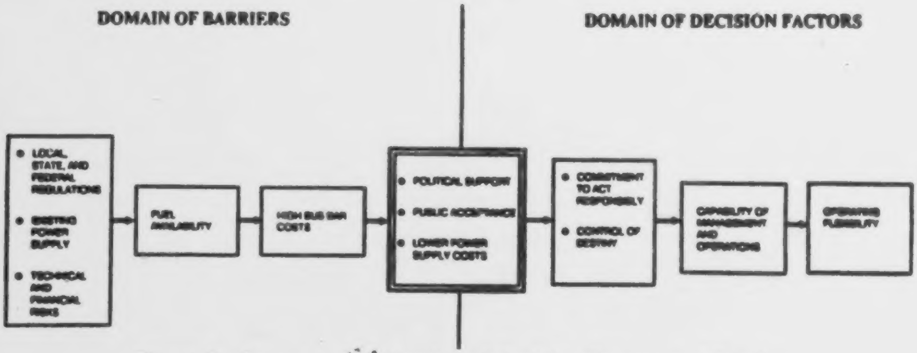

DOMAIN OF BARRIERS
DOMAIN OF DECISION FACTORS
• LOCAL, STATE, AND FEDERAL REGULATIONS
• EXISTING POWER SUPPLY
• TECHNICAL AND FINANCIAL RISKS
FUEL AVAILABILITY
HIGH BUS BAR COSTS
• POLITICAL SUPPORT
• PUBLIC ACCEPTANCE
• LOWER POWER SUPPLY COSTS
• COMMITMENT TO ACT RESPONSIBLY
• CONTROL OF DESTINY
CAPABILITY OF MANAGEMENT AND OPERATIONS
OPERATING FLEXIBILITY

Figure 3. Summary Combination of Decision Factors and Barriers

The traditional factors for evaluating generation additions -- cost and risk -- are important to public power. Experience of the participating utilities in APPA's recent demonstration project, however, suggests two very important points which will be tested in the completion of the market study:

1) Public power systems may sometimes be willing to pay more for fuel cells than traditional economic comparisons would suggest. They value the environmental and operating features quite highly, including the relatively small sizes offered by fuel cells; and

2) The risk that many smaller public power systems are able to accept in deploying a new technology like fuel cells is relatively low. A fuel cell power plant of one to 50 MW comprises such a large part of their capacity requirements that its performance must be highly reliable, even for early units.

Public power needs, or at least desires, new generation owned by municipal or joint action agency organizations. The deregulated direction that the U.S. electric utility industry is taking will provide a more competitive utility business, on the one hand, and more difficult inter-utility business transactions on the other. This trend, plus the traditions of public power, argues for replacing currently purchased power with self-generation if the costs and other factors tilt decision-makers in that direction.

Fuel Cell Features of Interest

As described in Section I and as presented in Appendix F, the interest of municipal electric systems in the fuel cell evolves from its numerous attractive, and unique combination of, features:

1) ***Size*** -- At one to 50 MW, no other technology offers such high efficiency. This technology is sized to meet the smaller capacity requirements of public power;

2) ***Part load efficiency with fast response*** -- many systems would prefer a technology capable of economic operation in a broad, intermediate duty range, possibly to include base load operation under certain circumstances;

3) ***Cogeneration potential*** -- most municipal systems will prefer cogeneration installations to increase public acceptance and the economics. Fuel cells are easier to site than other cogeneration technologies;

4) ***Environmental attractiveness*** -- urban power systems with generation within their urban boundaries will increasingly require very clean technologies. The lack of significant water requirements by fuel cells is a real plus in a significant portion of the U.S;

5) ***Low noise*** -- city-sited power plants must have noise characteristics that make them unobtrusive neighbors; and

6) ***Short lead time and modularity*** -- this adds up to building the capacity very close to the time that you need it. This is a real strategic benefit.

The market study report in preparation details several examples of utilities and joint action agencies that have developed a significant interest in the purchase of fuel cell power plants. The reasons for their interest offer significant insights that lead to the methodology for assessing the market:

- Certain utility characteristics seem to favor fuel cells, but the reasons for being an advocate or a leader vary significantly from utility to utility;
- Some municipal systems would prefer to own both peaking and intermediate supply capability, as they believe they will continue to purchase base load capability, often because of its low cost. Others, however, *do* foresee a baseloaded dispatch mode for fuel cells, especially with cogeneration.
- The desire for self-generation is rooted in interest in controlling one's future, particularly controlling costs;
- Systems that view themselves as environmentally constrained, today or eventually, are most likely to be early buyers of fuel cells. Some systems believe it is the *only* technology that they could build on or near their system;
- The early buyers will be manager-advocates with a vision of the future into which this technology fits. The boards or city councils will share at least the key elements of their vision; and
- Joint action agencies appreciate that this technology may reduce the need for transmission capacity linking their cities (among other advantages.)

Public Power Provides an Early Market Opportunity

In both characterizing and quantifying the market for fuel ce[illegible]t is clear that public power represents possibly the best early market for fuel ce[illegible]

Its need for the fuel cell's features allows public power systems to pay more for fuel cells than traditional economic analysis would suggest. Most markets for new products develop around a niche that can place a high value on the new product's features. This higher valuation is necessary because higher cost or higher risk to the buyer usually accompanies early market products. In our analysis, public power is not expected to accept extraordinary risk, but may accept higher than normal costs.

Certain environmentally-constrained utilities and forward-thinking joint action agencies see such value in the technology that they will take actions to accelerate the commercial availability of fuel cells and to accelerate their own readiness to consider broad application of the technology when it becomes economic. These organizations see their involvement with efforts to develop fuel cells as an opportunity to build capabilities to meet future requirements.

Interest in increased self-dependence to control costs, and interest in retaining expenditures locally over external purchases to promote community economic development, leads many systems to be interested in replacing power purchases with self-generation. This replacement need is not dependent upon slow, constant load growth, but is a requirement that exists as soon as current contracts expire. This presents a truly unique early market niche.

Public power is the largest potential market for fuel cells, and it may be the most accessible early market. The factors discussed above, and others, are being utilized to identify the magnitude of this particularly early market in comparison to the overall mature market in public power.

The Market Potential in Public Power is Large

APPA's quantification of the market is focusing on three applications:

1) Replacement of purchased power contracts;

2) Replacement of retired generation; and

3) Additions to meet load growth requirements.

The period of interest is from 1996, the earliest date when fuel cells may reasonably be commercially available, to 2010, a date by which more advanced technologies may be considered.

The analysis initially assumes that fuel cells are eventually competitive with other available options, no matter how each is valued. Examination of how much a system can afford to pay, and the effects of market penetration limitations, are considered later and will be reported in the study report. Given the still progressing status of the market study, only preliminary figures for the absolute or maximum technical market potential are reported here.

The methodology takes the following steps:

1) Replacement of Purchased Power

- Identify total purchases of each individual public power system;
- Subtract purchases from federal hydropower, individual municipal systems and joint action agencies on a utility-by-utility basis since these are not likely to be replaced; and
- Of this "replaceable" purchased power, assume that a maximum of 6% per year per utility is available for self-generation as contracts expire.

2) Replacement of Retired Generation

- Determine the total amount of generation installed on a utility-by-utility basis;
- Assume a fifty-year lifetime for existing capacity, thus defining the retired capacity requiring replacement on a year-by-year basis.

3) Additions to Meet Growth

- Where load growth data on individual systems exist, calculate capacity requirements year-by-year for each. Use an average load growth figure for the remaining utilities (also approximately the median of 2.25%);

- Determine the individual capacity requirement due to growth for each year for each system.

These three components of load growth, replaceable purchased power, and unit retirements are calculated and combined each year during the 1996 - 2010 period for each public power system. Combined requirements are matched against the power contributions from either 1-, 3-, 10-, or 50-MW units (based on capacity factors for baseload and intermediate units currently in place within public power systems) and, if the addition of the unit does not exceed current maximum dependence on an existing resource, it is counted as a potential purchase and the utility's new load requirements are reduced accordingly. If the combined requirements are *not* sufficient to accommodate a new unit at the given size, this new increment is carried forward to the next year when the evaluation begins again for that utility. This disaggregate analysis for each utility system is then summed for public power as a whole.

The evaluation of the four different unit sizes is intended to test whether the smallness of many public power systems is a limitation of market potential as a function of unit size.

The application of a "maximum dependence" ceiling on any given resource is meant to test the need to diversify resources and lower risk.

The analysis is then repeated in its entirety to investigate the role of joint action agencies. To prevent double counting, each joint action agency is treated as a composite of its individual members. These "synthetic" joint action agencies are then combined with the non-agency member individual utilities to provide an evaluation for public power as a whole under the influence of a predominant agency role.

The tables and figure that follow provide the results of this technical market analysis. The "early fuel cell markets" noted in Table 2 are evaluated using the same methodology, only restricted to a smaller subset of public power systems that meet early market criteria. Additional detail and illustrative figures are contained in Appendix E.

Table 1 presents the maximum market, for all three applications within which fuel cells must compete. Table 2 screens for utilities that meet certain criteria, as noted and assesses the markets within these subsets.

Table 1. Maximum Market Potential as A Function of Unit Size, 1996-2010

Unit Size (MW)	Individual Public Power Systems (no Joint Action Agencies)		Individual Systems Plus Joint Action Agencies*	
	No. of Systems	Cumulative MW Potential	No. of Systems	Cumulative MW Potential
0.25	1,682	129,405	934	304,226
1	1,422	91,484	768	303,065
3	1,068	89,982	599	302,268
10	604	85,920	357	299,980
50	191	75,350	143	293,850

NOTE: * Individual public power systems served by joint action agencies are included with the agencies to prevent double counting.

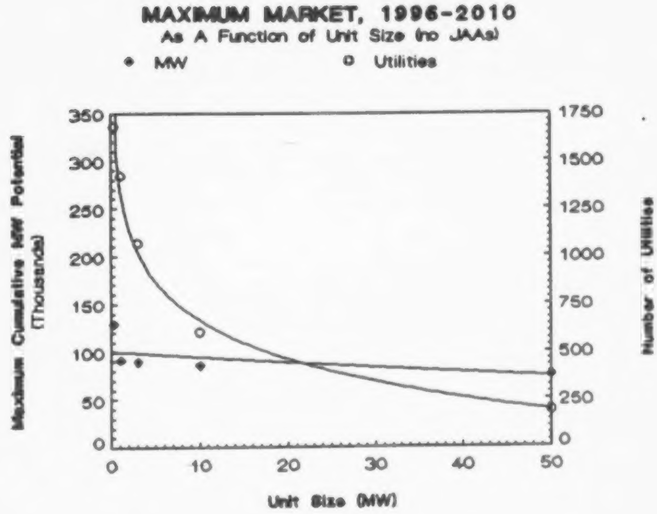
Table 2. Potentials for Early Fuel Cell Markets as a Function of Unit Size, 1996-2010

Unit Size(MW)	"Likely, Early" Market*		"Potential, Early" Market**		Early Market Small Market***	
	No. of Systems	Cumulative MW Potential	No. of Systems	Cumulative MW Potential	No. of Systems	Cumulative MW Potential
0.25	72	29,606	190	34,995	180	13,886
1	72	29,550	189	34,878	179	13,778
3	72	29,475	183	34,683	173	13,593
10	65	29,200	132	33,970	122	12,920
50	42	27,900	62	31,600	52	10,750

NOTES: * This group is comprised of public power systems most likely to exhibit an early interest in fuel cells. See Appendix E.

** This group is similar to the "likely, early" market, except current self-generation or a strong interest in self-generation is not used as a screening criteria.

*** This group is a subset of the "potential, early" market, absent the twenty largest individual public power systems (ten of which meet the screening criteria).



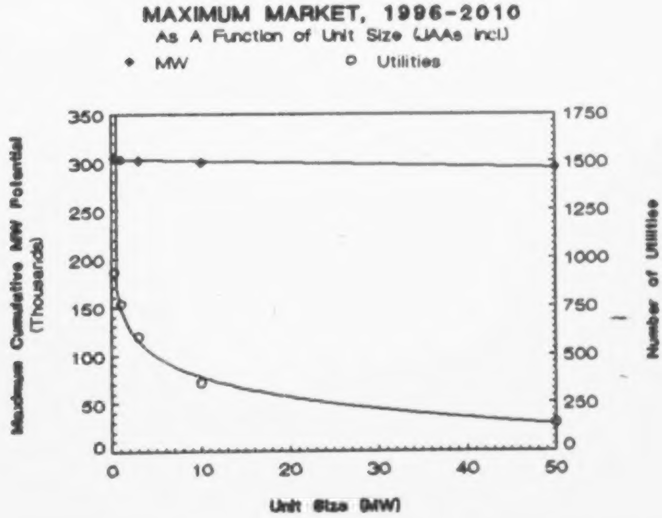


Figure 4. Maximum Potential Market as a Function of Unit Size

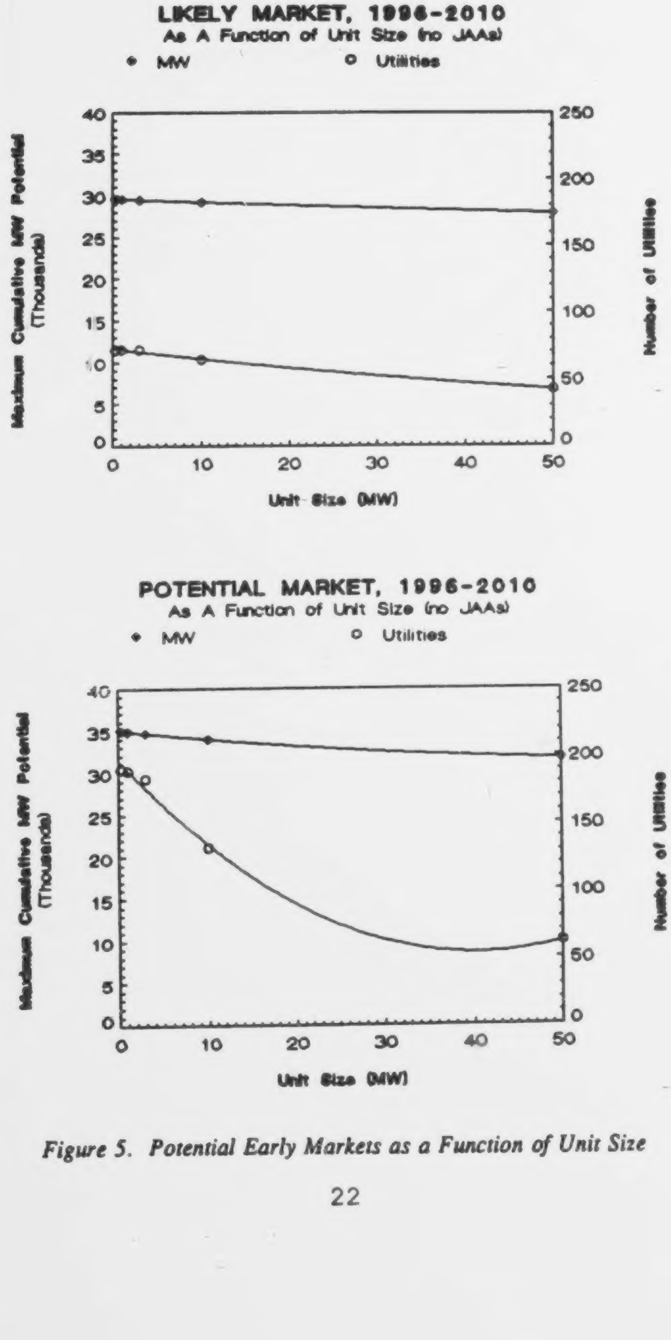


Figure 5. Potential Early Markets as a Function of Unit Size

III. POSSIBLE ACTIONS BY PUBLIC POWER TO HELP PROMOTE COMMERCIALIZATION

The exact nature of public power's actions to help promote fuel cell commercialization awaits responses to this "Notice of Market Opportunity." This section, however, describes past actions that have been taken either by APPA or its individual members to support commercialization. Given the proper circumstances, these example actions may be taken again.

APPA's prime interest is in finding appropriate actions of mutual benefit between public power and fuel cell manufacturers. We thus do not intend to limit public power's potential support to those example actions offered below. We encourage manufacturers to reply with their ideas for the role(s) and value(s) of public power actions.

NOMO But the First Step in Ongoing Process

This "Notice of Market Opportunity" is *not* a request-for-proposals. Through this invitation, we seek the voluntary exchange of information and ideas.

APPA and its reviewers fully expect that if a successful collaboration is to develop with a manufacturer(s), that the final relationship may bear only partial resemblance to the ideas presented in this NOMO or in the responses to it.

The primary purpose, then, for this NOMO is to frame a process leading to a set of shared commitments and objectives. We thus offer no definitive time frame for establishing a viable commercialization relationship, nor commit that such a process will develop.

For responses that so merit, APPA and its reviewers commit to an ongoing process for as long as is necessary to achieve ultimate objectives. Ultimately, if successful, APPA and its reviewers' intent is to take the resulting fuel cell commercialization plan to APPA's Board of Directors for endorsement, with direct solicitations or communications to APPA's full membership as appropriate.

Providing Market Information and Feedback

Already APPA has taken the unprecedented step of conducting its own market assessment on fuel cells (see further Sections II and V, and Appendixes E and F). Under appropriate protection of confidentiality, APPA is prepared to offer access to the raw data from which this assessment was derived.

APPA and its reviewers also stand ready to enter into a more interactive relationship of market feedback. Thus, specific questions of applications, potential purchasers, and the sharing of decision factors governing future power supply options may be explored.

Assistance in Reviewing Product/Commercialization Plans

APPA and its reviewers welcome a close relationship with manufacturers to assist in reviewing product designs for their applicability to public power systems. An earlier public power demonstration initiative defined key technical and operating parameters as part of its project plan. This information is available to any future efforts.

Fuel cell characteristics of interest were also included in an APPA survey. Summary results from that survey are reported in Appendix F. The survey data base is also available for more targeted analysis, should discussions with a manufacturer(s) so warrant.

The commercialization plan is a critical component to meet the objective of this NOMO for having fuel cells available for purchase no later than the mid-1990s. Review and refinement of these plans is therefore an integral part of any collaborative relationships begun with a manufacturer(s) as a result of this Notice.

Publicity and General Awareness Campaign

Prior APPA efforts in fuel cells have emphasized the Association's ability to increase awareness and to communicate with its members (and those of affiliated organizations such as state and regional associations and joint action agencies) and other interested groups. Four main avenues are possible for such an awareness campaign:

- Use of APPA and affiliated organization publications;
- Direct member communications;
- Showcasing at meetings sponsored by APPA and affiliated organizations; and
- Communications with outside groups.

APPA publishes a weekly eight-page newsletter and a bi-monthly seventy-page magazine. These publications reach all public power systems, plus many additional audiences. In addition, the Association's quarterly R&D publication, the sixteen-page *DEED Digest*, is circulated to 500 of the most innovative public power systems and about 1,000 other interested groups.

(In the case of APPA's earlier fuel cell demonstration efforts, a fuel cell booklet was also prepared covering all aspects of the technology and project. This document was never published due to the suspension of that effort. Preparation of a similar booklet may be possible again.)

These Association publications have a proven record in getting the message out.

APPA publications are also frequently the source of stories for the approximately 100 different newsletters published by APPA's affiliated organizations.

For a more targeted message or the dissemination of more detailed information, such as a product description, direct member communications are the favored approach. Due to the nature of the communications, specialized mailing lists by subject area or area of responsibility exist, as do, of course, public power-wide lists.

APPA conducts a number of major conferences each year, plus about sixty specialized workshops and training courses. Fuel cells have been featured at the general sessions of past conferences, and will likely be so again. A special workshop on fuel cells was held last October involving many invited speakers and discussion round tables. Such workshops, on either a national or regional basis, could be held again.

APPA's communications with outside groups include the use of press releases, testimony or direct letters to Congress, and staff liaison activities with appropriate professional societies and advocacy groups.

The common thread amongst all of these capabilities is the unique ability of APPA to speak to and for public power. As a relatively difficult sector of the electric utility industry to reach, APPA's efforts can be a key leverage point for marketing efforts.

Financial and Other Assistance for Demonstration Units

Two public power systems have signalled their intent in the 1980s to host multi-megawatt demonstrations of fuel cells. The first letter of intent was signed in 1982 by the City of Santa Clara, Cal., to demonstrate a 7.5-MW PAFC unit to be built by Westinghouse. The second demonstration, supported by a resolution of the city council of the City of Palo Alto, Cal., in 1987, involved a 11-MW PAFC unit to be built by International Fuel Cells. Both of these efforts have subsequently been suspended.

At one time or another, perhaps another ten or so public power systems have expressed interest in hosting the demonstration of megawatt-scale fuel cells under appropriate circumstances. A number of kilowatt-scale fuel cells have also been demonstrated by public power systems.

The most recent demonstration effort involving the 11-MW unit, however, also included a program of financial co-sponsorship by a broad base of public power systems. This initiative -- endorsed by APPA's Board of Directors but not formally initiated because of an inability to come to terms with the manufacturer -- called for the raising of about $20 million in financial co-sponsorship. This amount was to be in addition to the substantial contributions of the Palo Alto host site and the Electric Power Research Institute. The program called for financial co-sponsors to receive a slate of rights and benefits (including a say in the project's management) depending upon the level of contribution. While this effort was never formally announced, early commitments for about $8.5 million of the $20 million were received. APPA and its project team were confident of reaching the $20 million goal had the demonstration moved ahead.

Clearly, APPA and its members have proven their willingness to host or financially support fuel cell demonstrations. Under appropriate circumstances, such support may be forthcoming again.

Contingency Orders for "Early Production" Units

The 11-MW demonstration unit to be hosted by Palo Alto was originally part of a three- or four-unit demonstration program being spearheaded by EPRI. Unfortunately, the other non-public power segments of the U.S. electric utility did not commit to these other units.

Faced with being the only demonstration, APPA and its members took the initiative to resuscitate the effort by proposing a combined program consisting of a demonstration unit to be followed by contingency orders for "early production" units should the demonstration be successful. Within about six weeks, expressions of interest in six "early production" units were secured. APPA and the projects' steering committee were confident that a substantial number of additional orders could be secured. APPA's analysis indicated that 15 to 18 orders for such units were achievable within a reasonable time frame.

Unfortunately, the manufacturer deemed the risks of this approach to be too high, eventually leading to a suspension of discussions and the demonstration initiative.

In terms of the eventual objective of commercialization, however, a demonstration matched with contingency orders appears to be one of the most promising alternatives. Again, under appropriate circumstances, such support from APPA and its members may be forthcoming again.

Direct Relationships with Individual Public Power Systems

Nothing in this "Notice of Market Opportunity" should be perceived as foreclosing direct discussions with individual APPA members. In fact, given varying operating requirements and needs for new capacity, some of APPA's member reviewers or other public power systems may themselves choose to initiate discussions with manufacturers outside of the scope of this NOMO. Thus, while APPA and its member reviewers may *not* chose to pursue discussions with a given respondent to this NOMO, an individual public power system may choose to do so.

The premise behind this NOMO is that public power systems working in concert can exert more leverage with manufacturers and provide a more effective forum for manufacturers to get their message to public power. However, as noted repeatedly, this NOMO is not a request-for-proposals or proscriptive document. It should not be viewed by manufacturers as the only avenue available for communicating their capabilities to individual public power systems.

Other Alternatives

The above examples merely reflect the alternatives pursued by public power to date. APPA and its member reviewers welcome suggestions for other alternatives from the respondents to this NOMO.

IV. RECOMMENDED FRAMEWORK FOR RESPONDING TO THIS NOTICE

Only manufacturers that can realistically provide a commercial megawatt-scale fuel cell by the mid-1990s are requested to respond to this Notice of Market Opportunity.

This NOMO is not a request-for-proposals but rather a voluntary exchange of information to identify opportunities for workable and mutually beneficial relationships between public power and prospective manufacturer(s) to promote early commercialization of fuel cells. The level of detail and format to be provided in response to this Notice is solely at the discretion of the manufacturer. However, APPA and its member reviewers suggest a framework for responses. This section therefore offers recommendations on how to respond to the NOMO and suggests a checklist of topics to be covered.

General Instructions

Approximately twenty individuals will be reviewing responses to this NOMO, including APPA members, and APPA and EPRI staff. Insofar as practical, please follow these guidelines:

1) Be complete, but concise;

2) Unless twenty (20) copies of the response are to be submitted, refrain from including large charts, glossy brochures, etc., that would be difficult to photocopy;

3) At minimum, provide six (6) copies of your response;

4) If at all possible, restrict your response to non-proprietary data; and,

5) Provide the information indicated in this section and in Table 3.

If proprietary data are submitted, please so indicate. APPA will attempt to limit the dissemination of such information, but can provide no absolute guarantees. APPA will not release responses to any party except APPA members, APPA and EPRI staff, and APPA's contractors.

Responses are understood to be preliminary and voluntary; no quotation or citation will be made of information submitted without the expressed authorization of the respondent.

Since no formal scoring mechanisms will be imposed on the review of the responses to this NOMO, no weighting criteria apply to the various suggested topics to be covered.

Finally, APPA puts forward the invitation in this NOMO on a good-faith basis. APPA and its reviewers understand that respondents may be concerned that information put forward in their response may be misconstrued as a contractual offer or the beginning point of negotiations. This is not our intent. Our hope is that respondents will respond in a complete and open manner sufficient to build toward a set of mutual, shared objectives.

Suggested Topics

Table 3 offers a suggested checklist for responding to this Notice. APPA and its member reviewers recognize that depending on the completeness of product design, test and demonstration experience, and current corporate plans, that not all items on this checklist may be able to be addressed. Please be as complete as current information allows.

APPA and its member reviewers also appreciate that new product designs might result from the respondent's collaboration with public power. In such instances, please attempt to focus on the cost/design tradeoffs that will bound these product development decisions.

While not all topics in Table 3 may be able to be addressed at this time, at minimum please provide information in these areas:

- **Initial commercial powerplant description** -- including expected physical characteristics, expected performance characteristics, expected reliability and maintainability characteristics, estimated O&M requirements, expected scope of equipment to be supplied by the manufacturer, expected utility site-support requirements by the purchasing utility, and expected capital and operating costs;
- **Mature commercial powerplant description** -- including changes or improvements in technical, operational and physical characteristics that are expected, and estimated improvements in capital and operating costs;
- **Description of the current status of the technology**;
- **Commercialization plan and schedule** -- including commercialization objectives and timeline, and a description of the role perceived for APPA and its members in assisting commercialization; and
- **Description of the corporation** -- including annual revenues, employment, current commercial product lines, and ownership by major stockholders.

The commercialization plan should receive particular attention. Experience has shown that utilities will not pay an excessive premium over competitive price for demonstration, early commercialization, or mature units. The high up-front costs during early stages of commercialization can be subsidized by consortium demonstrations and contingency orders, as well as more traditional industry and governmental research programs, if the benefits for early participation and support are real.

Describe your commercialization plan in these simple terms, revealing any uniqueness in your approach. Indicate what you would provide to buying utilities in return for APPA or individual utility support. Although equity participation in a venture is unlikely (and may not be viable for publicly-owned systems), other options for sharing the results of success may be of interest, particularly price or other preferences.

Indicate what you would like to see in an APPA reaction to your response to this NOMO. Also indicate what tangible actions you would need to implement the technology development or commercialization efforts you have described.

Recommended Time frame for Response

APPA desires receipt of responses in its offices by close of business on February 1, 1989.

Table 3. Suggested Checklist for Responding to this Notice

I. Status of Product
  A. Laboratory/Test Stand Performance
    1. Hours at What Scale
    2. Achieved Performance
  B. Units in Operation at Non-Manufacturer Sites (non-electric utility)
    1. Summary of Sizes, Applications and Sites
    2. Operating Histories by Site
    3. Achieved Performance by Site
      a. MTBF (mean time between failures)
      b. Hours of Operation
      c. Shutdown/Startup Experience
      d. Cell Degradation Rates (mV/1,000 hrs)
      e. Role of Site Personnel in Operation
  C. Units in Operation at Electric Utility Sites
    1. Outline as Under I.B. Above
    2. Customer Plans for Additional Units
    3. Contact Name, Title, Phone at Utility Sites
II. Technology and Design
  A. General
    1. Net Power Output (MW)
    2. Heat Rate (LHV basis)
    3. Thermal Efficiency (%) (with waste heat recovery)
    4. Recoverable Waste Heat (LHV and temperature)
    5. Emissions

   - a. NO_x
   - b. SO_2
   - c. CO
   - d. CO_2
   - e. Hydrocarbons
   - f. Particulates

6. Sound Level (dB(a) at site perimeter)
7. Site Layout/Design (incl. enclosures or perimeter barriers)

   - a. Footprint
   - b. Profile (max. plant height)

8. Standard AC Voltage Output (kV)
9. Operating Pressures and Temperatures
10. Operating Parameters

    - a. Reactive Power Compensation (MVAr/sec)
    - b. Ramp Rate (MW/sec)
    - c. Cold Startup Time
    - d. Standby-to-Full Load Time
    - e. Plant Turndown Limits (turndown ratio)
    - f. Plant Shutdown Time
    - g. Mode of Operation (unattended, automated, etc.: Describe.)

11. Make-Up Water Requirements
12. Fuel Requirements During Different Operating Modes
13. Designed Economic Life (hrs) of Plant and Major Subsystems
14. Availability

B. Fuel Cell Stack Subsystem

1. Lifetime (hrs)
2. Degradation Rates (mV/1,000 hrs)

   - a. Achieved to Date
   - b. Design Goal

3. Module Size (kW), Dimensions and Configuration
4. Fuel Cell Area
5. Current Density (mA/sq. cm.)
6. Cooling Method and Rationale
7. Hours of Operation Achieved to Date

C. Fuel Processing (Reformer) Subsystem

1. General Description of Type
2. Module Size/Redundancy
3. Efficiency
4. Burner Description and Fuel Requirements
5. Preheater Description
6. Projected Tube Lifetimes/Replacement
7. Startup/Shutdown Histories and Performance

D. Power Conditioning (Invertor) Subsystem

1. General Description of Type
2. Efficiency
3. DC Input Specifications
4. AC Output Specifications
5. Distortion Factor
6. Operation

- a. Individual Module
  - i. constant voltage (%)
  - ii. constant frequency (%)
- b. Interconnected
  - i. effective power control (%)
  - ii. reactive power control (%)

E. Powerplant Control Subsystem

1. Parallel vs. Series Control Philosophy
2. Impact on Fuel Cell Stacks of Varying Ages
3. Stack Changout During Operation
4. Automatic Shutdown Processes
5. Other Control Modes

F. Ancillary Subsystems (describe fully)

1. Water Treatment (if required)
2. Fire and Safety Protection
3. Non-Fuel Consumables (catalysts/reagents)
4. Modifications to Design for Cogeneration

G. Summary of Transition of Design and Performance Characteristics from Demo to Early to Mature Units

H. Current Design Considerations that Serve to Improve Reliability

I. Potential Plant Simplifications to Meet Market Requirements/Improved Availability

J. Description of Fixed vs. Variable Trade-Offs

K. QA/QC Considerations in Current Development Efforts

L. Additional Unique Design Considerations

III. Description of Site and Construction Requirements

A. Relationships (if any) with Architect/Engineering Firms

B. Estimate of Labor Requirements During Construction

C. Estimate of Plant Footprint

D. Estimate of Additional Land Required During Construction

E. Description of Special Site Requirements (if any)

1. Grid Interconnection
2. Water Requirements and Quality
3. Fuel Hookups
4. Communications Requirements
5. Subfoundations
6. Cogeneration Limitations

IV. Plan for Provision of Ongoing Support

A. Spare Parts Requirements and Inventory

B. Commitment to Fuel Stack Availability during Plant Lifetime

C. Operator and Maintenance Training

D. Provision of Aids for Site-Specific Evaluations

E. Cost, Availability, and Retrofittability of Improved Fuel Cell Stack/Other Major Plant Subsystems (if planned)

F. Corporate Posture Toward O&M Contracts

V. Description of Manufacturing Capabilities and Planned Facilities

VI. Commercialization Plan

A. Cost Projections

1. Capital Costs for Demonstration Units ($/kW)
2. Capital Costs for Early Production Units ($/kW)
3. Capital Cost Objectives for Mature, Commercial Plants ($/kW)

    a. Number of installed plants/installed MW needed to meet objectives
    b. Anticipated time frame to meet objectives
    c. Performance and powerplant lifetime guarantees

4. O&M and Labor Requirements

B. Corporate R&D Expenditures to Date

1. Total
2. Corporate (unreimbursed)
3. Government Supported
4. Industry (customer supported)

C. Commercialization Objectives

D. Commercialization Timeline

E. Interest in Contingency Orders and Commitment Expected by Buyers and Seller

VII. Description of Longer-Term Development Objectives (after initial commercialization)

A. Performance Improvements for Major Plant Subsystems

B. Cost Reductions for Major Plant Subsystems

VIII. Suggested Alternatives for Working Collaboratively with Public Power

(See further Section III.)

IX. Corporate Description

A. Annual Revenues, Sales and Employment

B. Description of Current Commercial Product Lines

C. Description of Ownership by Major Stockholders

V. FOR FURTHER INFORMATION

Questions regarding this NOMO should be addressed to:

Michael K. Bergman
Director of Energy Research
American Public Power Association
2301 M Street, N.W.
Washington, D.C. 20037
ph. 202/467-2941

A number of supporting documents are also available from APPA. Unless otherwise noted, these documents are available upon request for the price of reproduction:

- *Screening of Small Utilities for Potential Fuel Cell Application*, prepared for EPRI by Burns & McDonnell, December 1980, 45 pp.
- *The Need for a Fuel Cell Power Plant Demonstration Among Locally Owned Utilities*, prepared for APPA by Burns & McDonnell, March 1981, 43 pp.
- *Report of APPA's Fuel Cell Development Group*, May 1987, 107 pp.
- *The Market for Fuel Cell Power Plants for Municipally-Owned Electric Utilities*, prepared for APPA by Technology Transition Corp., Dec ember 1988. (in final preparation) ($750)
- *Fuel Cell Feasibility Study*, prepared for APPA by the City of Palo Alto, Cal. November 1988, 126 pp.

In addition, these general APPA publications may be of interest:

- *1988 Public Power Directory*, 95 pp. ($40)
- *Public Power in America: A History*, 23 pp.
- *The Public Benefits of Public Power*, 19 pp.
- *DEED Digest* (16 pp. quarterly R&D newsletter) ($150 annually)

APPENDIX A:

WHAT IS PUBLIC POWER?

WHAT IS PUBLIC POWER?

More than 35 million Americans in every state but Hawaii receive electricity from 2,200 nonprofit, community-owned, locally controlled electric utilities. Public power is as old as the electric utility industry itself. In customers served, it is the second largest segment in the nation's diverse electric utility industry, providing electric power to about 14% of all customers.

Local power systems are deeply rooted in the history of the United States by more than a century of public service. They were created on the premise that electric power is a public business, and is either owned and operated by the public or regulated by the public when the service is provided by private parties.

Public power today is an important contemporary American institution. From small towns to big cities, wherever public power exists, it is an expression of the American ideal of local people working together to meet local needs.

Public power consumers have a special relationship with their utility. They are owners as well as users. Local control means having a voice in utility policies. Putting electric utility control in public hands can greatly improve the quality of life for the entire community by providing adequate and reliable electricity at the lowest possible cost, service shaped to meet local needs, economic development assistance, and a special commitment to innovation and wise use of energy.

Also, public power is a strong competitive force which provides a "yardstick" for measuring the performance and rates of private power companies. That helps electric consumers everywhere.

The remainder of this appendix provides a brief history of public power, describes its relationship to the rest of the U.S. electric utility industry and public power's diversity, highlights the importance of community ownership and its impact on utility decision making, and notes APPA's role as public power's national service organization.

A Brief History of Public Power

Two local public power systems in the Midwest actually had lit their courthouse squares well before Thomas Edison first delivered electricity from his Pearl Street central generating station in New York City in September, 1882. They were forerunners of the 2,200 local publicly owned power systems in the United States today.

Citizens of many other municipalities were quick to follow. Civic pride and determination by local people to join the nation's march toward progress loomed large in the scheme of things.

Just six years after Edison's widely publicized 1882 venture, 53 municipalities operated their own light and power systems. In the next two years, the number almost tripled. During the 1890s, public power began to hit full stride and local systems multiplied at a rapid pace, as did private power companies during this period.

By 1900, there were some 800 municipal electric systems and about 2,200 private investor-owned utilities. Public power operated in towns from Maine to California, from Washington to Florida. Of the nation's first 800 municipal systems, established in the 1880s and 1890s, 228 in 36 states are still providing their local citizens with reliable nonprofit electricity.

In the early days, the largest concentrations of public power systems were in Great Lakes states and the central part of the nation. Mostly they were small communities that could not obtain electric service from privately owned companies. Lighting Main Street was not profitable in the early days. Less populous areas found themselves having to serve themselves or do without. Municipal ownership was simply a practical solution. It also was less costly. Nonprofit local ownership meant operating costs could be about half of private costs, according to an 1887 survey.

By 1920, there were more than 6,500 electric light and power systems in the United States. Local public power reached its peak in 1923, when 3,066 municipal systems delivered electricity. Private power companies had hit a high in 1917 of 4,224.

The number of both public power systems and private companies started to fall off during the mid-1920s. However, the number of private utilities declined more precipitously -- largely due to a rapid trend toward mergers and consolidation. They became fewer in number, but larger and more centralized. During the late 1920s and early 1930s, municipal systems outnumbered private power companies, although the privates continued to serve a lion's share -- about 90% -- of the ultimate electric consumers.

Public power also began to taper off to approximately its present level of around 2,200 systems. The trend toward private consolidation continued and today there are only about 200 investor-owned electric utilities.

The 1920s also witnessed new technology that had a significant impact on the electric utility industry. Long-distance transmission, plus larger and more efficient generators, made it more attractive for municipalities to develop distribution systems and to purchase power at wholesale from a central supplier -- in those days, a private company. Many public systems abandoned generation altogether and became solely distributors.

As the nation adjusted to the increased influence and significance of the electric power industry, other strong forces also were beginning to stir. They would have an enormous impact on public power and, in fact, helped fashion the future of the entire utility industry. Chief among these was the federal government.

President Theodore Roosevelt (1901-1909) was a champion of government development of the nation's rivers for low-cost hydroelectric power. He was steadfast in his belief that the benefits of hydropower should flow directly to the people through public control rather than private.

Implementation of this philosophy began with passage of the Reclamation Act of 1906. The law specified that municipally owned power systems be given first purchase rights to surplus hydropower from federal irrigation projects.

Thus, the "public first benefit" right was installed as a matter of law and national policy. The policy has been reaffirmed by Congress in more than 30 statutes since 1906.

The stock market crash in 1929 and the monopolistic excesses of private holding companies led to the Public Utility Holding Company Act of 1935. Partially breaking up the "Power Trust," the law directed private conglomerates -- comprised of 16 holding companies controlling 85% of U.S. power supply -- to split their holdings into smaller, regional systems and to separate gas and electric holdings. The Securities and Exchange Commission began to oversee holding companies. The Federal Power Commission (now the Federal Energy Regulatory Commission) was given power to regulate interstate wholesale electric power rates -- since such interstate sales were beyond the reach of state utility commissions.

In the 1930s, the federal government assumed a more active role in promoting federal hydropower projects. Three major federal power-related agencies were created. The first was the Tennessee Valley Authority, created in 1933 as a corporate agency of the government and charged with broad resource development -- including power -- throughout the multi-state Tennessee Valley region. In the mid-1930s the Rural Electrification Administration was created to provide low-cost loans for bringing power to the farm. And in 1937, Congress created the Bonneville Power Administration to market hydropower from the Columbia River in the Pacific Northwest.

Eventually, a total of five federal power agencies were created, which market power from 132 hydropower projects in all parts of the U.S. except the Great Lakes region and New England. Approximately 1,100 public power systems and rural electric cooperatives in 34 states and serving 38 million Americans rely on power from these federal projects for all or part of their power supply. However, the era of these large federal projects now appears to be ending with few new projects being authorized in recent years.

As local public power entered the second half of the 20th century, the future was promising. Use of electricity was still doubling every decade; average size of generating plants had increased sevenfold, thereby reducing power production costs; the "all-electric" home invited postwar America to live better electrically; and the price of electric energy per unit continued to fall.

Between 1950 and 1970, local public power systems focused on improving power supplies. Publicly owned utilities obtain power supply in two ways: self-generation; and purchase from another supplier. Self-generation took a dramatic turn in the late 1950s when public power began establishing joint-action agencies. To capitalize on the greater efficiency of large scale generation and transmission, groups of municipal systems united to form their own electric power agencies and built facilities large enough to serve a number of cities and towns, sometimes crossing state lines. By the late 1980s, the number of public power joint-action agencies was approaching 60.

But neither public power nor private power were immune from the Arab oil embargo of 1973-1974 that dramatically changed the world's energy outlook. Oil soared from $3 to $35 per barrel. Prices for competing fuels also skyrocketed. Consequently, the price of electricity rose sharply. The nation responded to a call for conservation, and consumer demand dropped for the first time in three decades. Gone was the 7% annual growth rate for electricity. Runaway inflation and the cost of environmental protection also helped drive up the cost of power.

The period from 1973 until the early 1980s was one of industry-wide challenges. The historical tensions between public and private power were subsumed in the industry-wide effort to hold the line on rates and restore public confidence.

Yet with the recent decline in oil prices and inflation, competition between public and private power has again begun to heat up, only now with a new twist: the emergence of independent power producers. Challenges to the concept of public preference to federal hydropower have been mounted. Limits to the use of tax-exempt financing for power projects involving private utilities have been imposed. Private utilities have become more aggressive in efforts to consolidate, diversify into non-regulated businesses, and buy up municipal electric systems. The Federal Energy Regulatory Commission has proposed sweeping changes to restructure the industry, acting to deregulate power supply.

These challenges, and others covered in Section I, provide the rationale for the renewed interest of many public power systems in self-generation.

Public Power Is an Important Part of a Diverse U.S. Power Industry

Four major industry segments, rapidly being supplemented by a fifth, provide the United States' electric power supply requirements. These are the: private utilities (investor-owned utilities, or IOUs); rural electric cooperatives; federal agencies; public power systems; and the emerging class of cogenerators/independent power producers.

In terms of traditional electric utilities, the IOUs, rural coops and public power supply electricity at retail to ultimate consumers; federal utilities supply power at wholesale only. All told, there are about 3,300 individual utilities in these four categories. An additional 2,800 cogenerators/independent power producers also supply electricity, though generally to a single customer (themselves).

Figure A-1 presents the relative importance of the major electric utility segments in terms of number of systems and customers served. Though cogenerators/independent power producers still serve relatively few customers, thus being excluded from Figure A-1, they have been the most important category in terms of new capacity additions in recent years, accounting for 75% of the total capacity added since 1980.

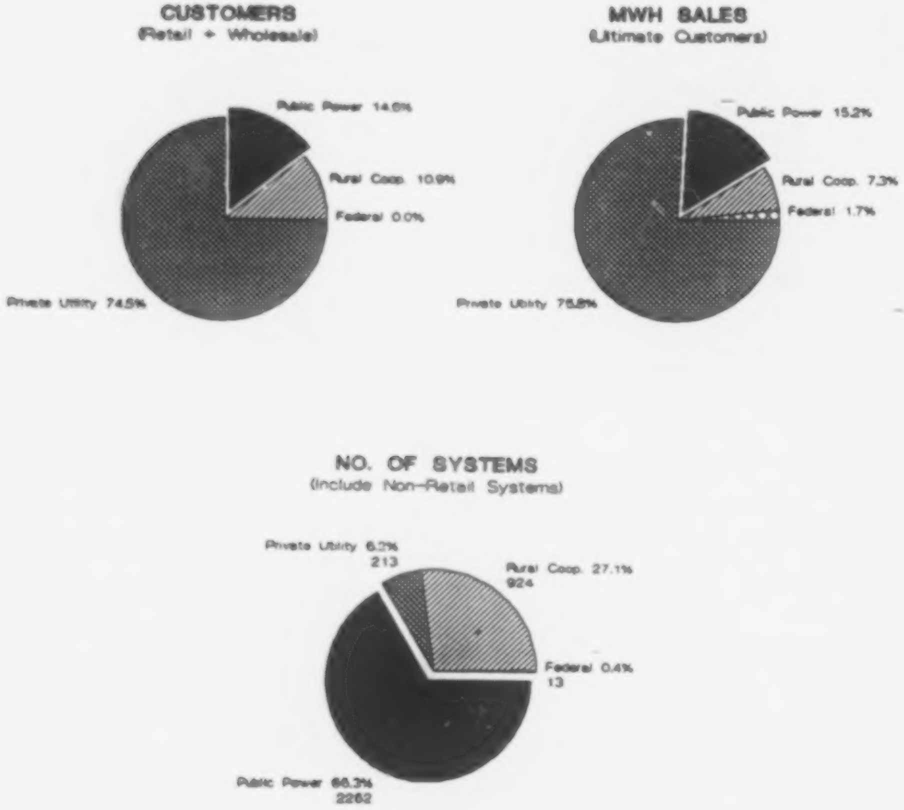


Figure A-1. Relative Importance of Major Electric Utility Segments

The three types of electric utilities that provide electricity at retail have widely divergent characteristics, as shown by Table A-1.

Table A-1. Summary Comparison of U.S. Retail Electric Utilities

	No.	Average No. of Customers	Percent of Total Installed Capacity
Private Utilities	213	364,660	74.9%
Public Power Systems	2,203	6,900	12.5%
Rural Electric Cooperatives	865	13,130	3.7%

Note: "Percent of Total Installed Capacity" does not add to 100% due to exclusion of federal utilities.

The most obvious observation is the very large number of public power systems of very small size. Additional summary statistics comparing the major electric utility sectors are shown in Table A-2. Not shown in Table A-2, however, is the fact that public power's rates are the lowest in the industry, averaging 30% less than those for private utilities.

This diversity based on ownership indicates that the "market" for new generation within the electric utility industry is anything but monolithic. Differences in growth rates, in regional fuels availability and energy prices, in public attitudes, in the degree of competition between utilities and alternative energy forms, and environmental constraints further fragment the U.S. electric utility market.

Yet efforts to date by prospective manufacturers to develop multi-megawatt fuel cells have not recognized this market fragmentation. Consistently their marketing efforts have targeted the large, integrated private electric utilities. Emphasis has been placed on where the size of the absolute market for new generation is largest, not where the fuel cell's unique characteristics can best compete.

Table A-2. U.S. Electric Utility Statistics

NUMBER OF CUSTOMERS (non-resale, except Federal)	Local public systems	15,212,070	14.6
	Private	77,672,000	74.5
	REA borrowers	11,357,105	10.9
	Federal	15,306	0.01
	TOTAL	104,257,431	100.0
KWH SALES (to ultimate customers, in millions of kWh)	Local public systems	326,943	14.0
	Private	1,787,000	76.8
	REA borrowers	172,965	7.4
	Federal	41,427	1.8
	TOTAL	2,328,335	100.0
ELECTRIC OPERATING REVENUES (in thousands of dollars, to all customer	Local public systems*	$25,327,000	13.5
	Private	135,808,804	72.1
	REA borrowers	19,942,767	10.6
	Federal	17,182,553	3.8
	TOTAL	$188,261,120	100.0
NET ELECTRIC PLANT INVESTMENT (in thousands of dollars; does not include nuclear fuel)	Local public systems*	$52,719,030	11.6
	Private	330,499,703	72.5
	REA borrowers	44,566,146	9.8
	Federal	28,329,219	6.2
	TOTAL	$456,114,100	100.0
INSTALLED CAPACITY* (in thousands of kW)	Local public systems*	89,115	12.5
	Private	535,709	74.9
	REA borrowers	26,098	3.7
	Federal	64,028	9.0
	TOTAL	714,950	100.0
KWH GENERATION* (in millions of kWh)	Local public systems*	276,045	10.7
	Private	1,937,212	75.1
	REA borrowers	120,832	4.7
	Federal	244,075	9.5
	TOTAL	2,578,164	100.0

Local public system statistics are from the American Public Power Association. Private company figures are from the Energy Information Administration. Rural electric data are from the Rural Electrification Administration. Federal power statistics are compiled from annual reports of the federal power marketing agencies and data reported to APPA.

*Includes joint action agencies.

Public Power Itself Is Diverse

The geographic distribution of public power systems is shown in Figure A-2.

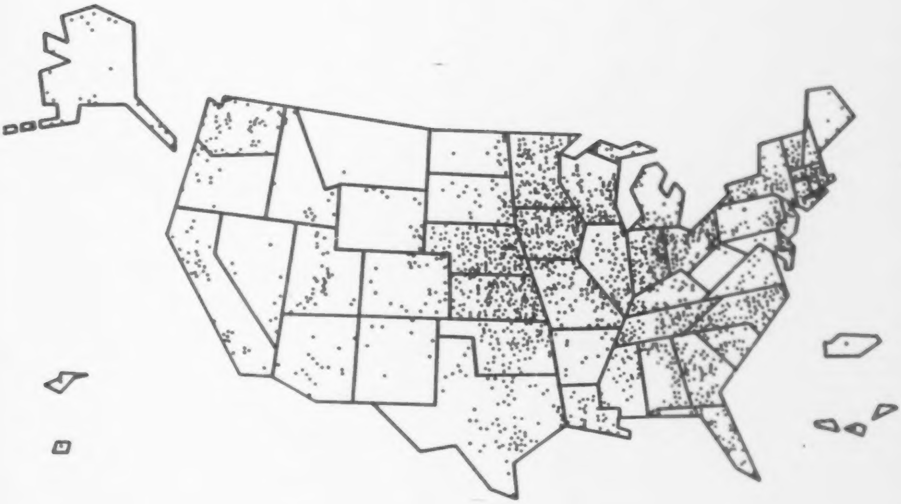
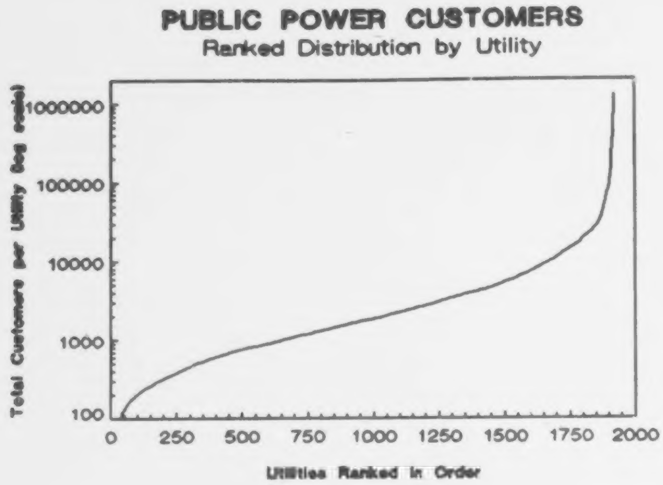


Figure A-2. Map of Public Power Systems in the U.S.

As shown in Table A-1, the average public power system is small. Yet some of the largest cities in the U.S. have chosen public power, including Los Angeles, San Antonio, Austin, Memphis, Nashville, Seattle, Orlando, Omaha, Jackson, Anaheim and Sacramento. The size disparities between the largest and smallest public power systems is reflected in two statistics: more than 70% of all public power customers are served by fewer than one-tenth of the systems, and the median-sized public power system has about 1,650 customers (representing a community of slightly more than 4,000 people). The startling range of sizes of public power systems is shown in Figure A-3 where all public power systems are sorted and plotted by customer size and sales.



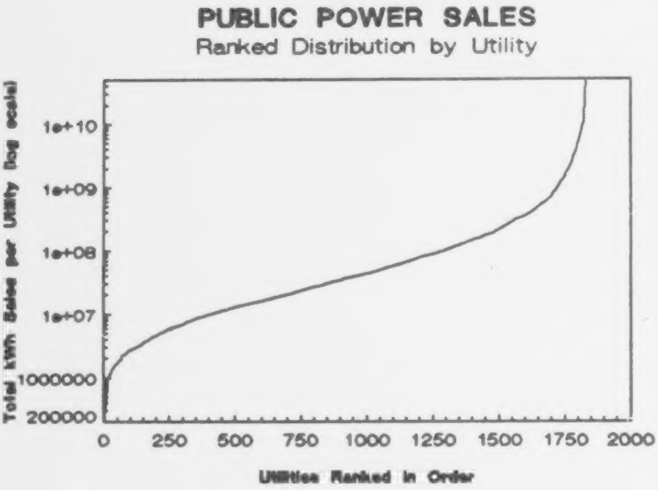


Figure A-3. Ranked Distribution of Public Power Systems by Size

Like the other segments of the electric utility industry, diversities due to regional fuels availability, costs, rates, etc., occur within public power. These diversities are important and are covered in more detail in Appendix B. Two other sources of diversity, however, not shared by private utilities deserve comment.

The first factor is that three-quarters of all public power systems are distribution-only utilities with no generating capacity of their own. Many of these had capacity in the past -- and may do so again. Generally, these are the smaller public power systems which were not able on their own to compete with the larger generating capacities and economies of scale that characterized generation trends from the 1950s to early 1970s.

The second factor, itself a response to the first factor above, is the creation and emerging importance of "joint action agencies." The agencies provide a means for public power systems to band together to jointly build powerplants or negotiate bulk power contracts. About 850 public power systems now belong to about 60 agencies that are found in most states. As capacity additions have slowed in recent years, many of these agencies have broadened the scope of support services they offer to their individual utility members.

Both the smaller individual systems that currently have no generation and the joint action agencies will have an important influence on fuel cell markets within public power.

The Importance of Community Ownership

In public power communities, the utility is governed locally and operated to provide citizens an essential service at an economic price. Municipal electric utilities are part of local government, like schools, parks, police and fire protection.

Public power systems belong to the people they serve. Many are controlled by the city's elected governing board, such as a town council. Others are governed by a utility board whose members may be elected or appointed by the council or mayor. No matter which option a community chooses, citizens have power to decide who controls utility policies.

Private power companies are often called "public utilities" because they provide a "public" service. But they are not like public power systems. They sell electricity for profit, which is included in the rates their customers pay. Profits go to stockholders all over the country.

The opposite is true of public power systems. They are not in business to make a profit for private owners. All of the benefits of public power produced at home stay at home -- in the form of lower rates, improved services, and other contributions to the community.

Responsiveness possible in a local public power system takes on new meaning in an age of conflict between economic and environmental values. People continue to want reliable electric service. But a clean environment and safety also rank high among their priorities. Local control of an electric utility and direct citizen involvement can help communities reach wise, balanced decisions about these issues.

Because public power systems are generally smaller and locally controlled, they are able to experiment more freely than large organizations with new and more efficient ways of producing and conserving electricity. Also, they are in a unique position as part of local government to integrate their services with other community functions --such as sanitation, water supply and recreation -- to better meet broad public service goals.

APPA Is the Voice for Public Power

The American Public Power Association, established in 1940, is the national organization representing non-profit, community-owned electric utilities. APPA represents more than 1,750 such public power systems.

APPA provides legislative and regulatory representation, information, training, and other services in the areas of public policy, engineering and operations, energy research, accounting and finance, human resources, and communications.

APPA is located in Washington, D.C., with a staff of 65.

APPENDIX B:

QUANTITATIVE PROFILE OF PUBLIC POWER

QUANTITATIVE PROFILE OF PUBLIC POWER

Public power systems are diverse in terms of size, ownership and role with respect to wholesale or retail power supply. For the purposes of this NOMO, we have chosen to categorize public power in different ways to highlight this diversity:

- Individual retail systems -- these are municipal systems or public utility districts that serve a substantial retail load (though systems which have important wholesale responsibilities as well as retail, such as the South Carolina Public Service Authority (Santee Cooper), Moncks Corner, S.D., and Grant Count Public Utility District, Ephrata, Washington, also are included in this category).

- Major joint action agencies -- these are power supply entities comprised of individual retail systems as members. These entities either own their own generation or act as a common negotiator for the purchase of wholesale power. These entities are listed in Table B-8.

- Other wholesale suppliers and agencies -- these are wholesale suppliers only, such as the state-owned New York Power Authority, New York, N.Y., and the Grand River Dam Authority, Vinita, Okla., or irrigation-only systems. Joint action agencies that provide power pooling functions, or shared transmission ownership only are also included in this category. These entities are listed in Table B-9.

- Twenty largest ("Top 20") retail systems -- since twenty public power systems serve nearly 40% of the customers served by public power, this group has been separately categorized. These systems are listed in Table B-7.

- Balance of individual systems -- these are the individual retail systems minus the three immediate categories above.

The following tables and charts profile public power systems using these categories. Comparisons to the other industry segments of investor-owned private utilities, rural electric cooperatives (rural coops), and federal systems (for a description of these segments see Appendix A) are also made.

Non-public power statistics are drawn from various published reports of the U.S. Department of Energy's Energy Information Administration and the Edison Electric Institute's *Statistical Yearbook*. Public power statistics are from APPA.

Table B-1. Public Power Comparisons With Industry Totals

	Total Electric Utility Industry	Investor-owned Utilities	Public Power
Total System Peak (MW)	476,320	---------	90,149
Retail Sales (GWh)	2,355,311	1,808,035	361,946
Residential	820,826	594,001	116,325
Commercial	630,260	518,602	81,723
Industrial	817,396	637,147	116,334
Other	86,829	58,285	26,586
Retail Customers (000s)	103,623	78,717	15,271
Residential	91,597	69,548	12,117
Commercial	11,180	8,535	1,580
Industrial	502	364	108
Other Retail	343	268	287
Retail Revenue ($000000)	$152,814	$121,072	$ 20,113
Residential	61,030	46,240	7,009
Commercial	45,738	38,379	6,507
Industrial	40,777	32,621	5,173
Other	5,269	3,832	1,425
Total Nameplate Generating Capacity (MW)	707,684	544,199	89,116
Conventional Steam	524.136	432,601	56,818
Hydro	85,165	28,949	18,957
Nuclear	92,417	80,213	9,986
Internal Combustion	5,944	2,420	3,289
Total Electricity Generated (GWh)	2,487,310	1,928,199	276,045
Conventional Steam	1,780,853	1,469,751	156,427
Hydro	290,844	71,356	78,405
Nuclear	414,038	386,513	39,786
Internal Combustion	1,556	565	1,235
Net Electric Plant in Service ($000000)	----------	----------	$ 39,039
Total Net Electric Plant Investments ($000000)	---------	$330,499	$ 52,719
Transmission-Total Circuit Miles	611,929	482,798	59,110
Total Number of Employees	---------	519,046	79,945

Source: "Total Electric Utility Industry" and "Investor-Owned Utilities" are based on U.S. Department of Energy's Energy Information Administration as reported in the Edison Electric Institute's *Statistical Yearbook -- 1987.* "Public Power" is based on APPA statistics. Note: Some "Total Industry" totals may be off due to public power undercounting in the EEI yearbook.

Table B-2. Public Power Comparisons With Industry Averages per System

	Total Electric Utility Industry	Non-Public Power Utilities	Public Power Utilities
Ave. System Peak Demand (MW)	144.6	354.0	68.0
Ave. Annual Load Growth (%)	2.1%	1.8%	4.0%
Ave. Load Factor (%)	60.7%	64.7%	61.6%
Ave. Total Annual Sales (MWh) to Ultimate Customers	715,030	1,827,100	311,818
Ave. Number of Retail Customers	31,460	80,980	7,150
Ave. Generating Capacity per System (MW)	195	510	42
Ave. Generation per System (MWh)	686,840	1,820,725	169,650
Ave. kWh Generation per kW of Capacity	3,562	3,514	4,015
Ave. Revenues per System ($000) from Ultimate Customers	$ 46,392	$121,632	$ 12,065
Ave. Monthly Residential Bill (1000 kWh)	$ 77.50	---------	$ 50.84
Ave. Number of Employees	---------	2,435*	63

NOTE: Excludes federal systems.
*Investor-owned (private) utilities only.

Table B-3. Comparative Totals by Public Power Structure

	All of Public Power	Major Joint Action Agencies	Other Wholesale Suppliers and Agencies	Top 20 Retail Systems	Balance of Individual Systems
Hourly System Peak (MW)	90,149,900	7,552,700	6,218,200	32,597,000	43,782,000
Number of Residential Customers =	12,117,000	N/A	0	5,582,000	6,483,000
Number of Commercial Customers =	1,579,720	N/A	223	653,320	920,290
Number of Industrial Customers =	108,424	N/A	63	43,470	64,815
Number of Other Customers =	286,937	N/A.	326	82,031	204,063
Number of Customers -- Total Retail Sales =	15,277,050	N/A	1,163	6,386,733	8,830,821
Number of Resale Sales Customers =	1,813	552	137	175	949
Numbers of Meters Served =	15,220,250	942	1,364	6,386,908	8,831,031

Residential MWh Sales =	116,324,700	0	0	51,951,000	64,373,690
Commercial MWh Sales =	81,723,030	0	48,754	38,242,070	43,432,210
Industrial MWh Sales =	116,333,600	0	14,650,750	39,626,190	62,056,680
Other MWh Sales =	26,585,510	584,350	12,196,030	5,740,132	8,065,003
Total Retail MWh Sales =	506,350,600	6,914,568	28,181,970	135,559,400	335,694,700
Resale MWh Sales =	145,753,800	45,156,210	46,025,730	15,931	38,640,350
Total Sales MWh Sales =	652,322,200	52,070,780	74,207,700	151,490	374,552,800
Residential Revenues ($000) =	7,008,697	0	0	3,135,659	3,873,038
Commercial Revenues ($000) =	6,506,854	0	1,462	2,528,523	3,976,867
Industrial Revenues ($000) =	5,172,782	0	293,212	1,991,534	2,888,036
Other Revenues ($000) =	1,425,049	24,751	639, 969	321,707	438,622
Retail Sales Revenues ($000) =	20,114,080	24,751	934,644	7,977,424	11,177,270
Resale Revenues ($000) =	4,114,879	2,004,741	820,243	477,622	842,272
Total Sales Revenues ($000) =	25,327,700	2,029,492	1,801,540	8,455,047	13,041,630
Net Electric Plant in Service ($000) =	39,038,900	5,087,024	4,328,518	15,141,960	14,481,390
Total Net Electric Plant Investments ($000) =	52,719,040	12,699,580	4,949,493	19,507,570	15,562,390
Number of Full-Time Employees =	79,945	2,032	2,785	35,946	39,182
Amount of Power Purchased -- Federal Agency (MWh) =	119,956,000	2,885,142	11,961,740	45,663,850	59,445,270
Amount of Power Purchased -- Investor Owned (MWh) =	65,634,780	14,801,770	2,677,538	7,262,714	40,892,760
Amount of Power Purchased -- Cooperative (MWh) =	10,710,260	1,932,741	103,401	682,311	7,991,810
Amount of Power Purchased -- Municipal (MWh) =	26,095,590	1,560,862	1,683,975	3,912,872	18,937,880
Amount of Power Purchased -- Industry (MWh) =	2,413,790	586,850	13,256	12	1,813,672
Amount of Power Purchased -- Cogeneration (MWh) =	1,042,775	0	0	113,430	929,345
Amount of Power Purchased -- Other (MWh) =	20,013,250	1,504,878	9,508,665	560,072	8,439,633
Amount of Power Purchased -- Total (MWh) =	422,610,700	30,442,380	26,649,370	59,926,160	305,592,800
Amount of Energy Obtained through J.A.A. (MWh) =	43,884,000	7,170,141	0	1,730,893	34,982,970
Total Nameplate Generating Capacity (MW) =	89,116	9,619	11,488	34,600	33,408
Total Electricity Generated During Year (MWh) =	354,912,700	32,640,130	54,819,710	103,120,200	164,332,700
Capacity Steam Turbine -- Total (MW) =	48,374	5,234	2,252	23,117	17,771
Capacity Steam Turbine -- Oil (MW) =	9,056	58	0	8,361	637
Capacity Steam Turbine -- Coal (MW) =	23,484	3,844	1,275	8,505	9,861
Capacity Steam Turbine -- Gas (MW) =	9,358	107	39	5,080	4,133
Capacity Steam Turbine -- Dual-fuel (MW) =	4,918	15	883	1,100	2,920
Capacity Steam Turbine -- Geothermal (MW) =	480	350	55	72	3
Capacity Nuclear Steam Turbine -- Total (MW) =	9,986	2,600	1,896	2,783	2,707
Capacity Gas Turbine -- Total (MW) =	5,644	416	0	1,829	3,399
Capacity Combustion Engine -- Total (MW) =	3,289	286	0	155	2,848
Capacity Hydro -- Total (MW) =	18,957	51	7,340	5,708	5,857
Capacity Cogeneration -- Total (MW) =	927	106	0	334	487
Total Transmission Circuit Miles =	59,110	3,700	3,465	19,598	32,347

Table B-4. Comparative Averages by Public Power Structure

	All of Public Power	Major Joint Action Agencies	Other Wholesale Suppliers and Agencies	Top 20 Retail Systems	Balance of Individual Systems
Number of Systems:	2,092	48	42	20	1,982
Average System Peak Demand (MW)	68	254	487	1,629	36
Average Annual Load Growth (%):	4.00	N/A	16.72	3.76	3.80
Average Load Factor	61.63	95.33	--	53.05	56.12
Average Annual Total System Sales (MWh):	311,818	1,084,808	1,766,850	7,574,546	188,977
Percent System Sales by Class.					
Residential:	23.90	0.00	0.00	34.29	29.72
Commercial:	16.79	0.00	0.07	25.24	20.05
Industrial:	23.90	0.00	20.09	26.16	28.65
Other Retail:	5.46	1.28	16.72	3.79	3.72
Resale:	29.95	98.72	63.12	10.52	17.84
Average Number of Total Customers:	7,148	14	27	319,345	4,322
Percent Total Customers by Class:					
Residential:	85.97	0.00	0.00	87.75	84.49
Commercial:	11.21	0.00	29.77	10.27	11.99
Industrial:	0.77	0.13	8.41	0.68	0.84
Other Retail:	2.04	1.06	43.52	1.29	2.66
Resale:	0.01	98.94	18.29	0.01	0.01
Average Generating Capacity per System (MW):	42	198	262	1,730	17
Average Generation per System (MWh):	169,651	680,003	1,305,231	5,156,009	82,911
Average kWh Generation per kW of Capacity:	4,015	3,440	4,977	2,980	4,935
Average Self-Generation (% of Total Sales):	54.41	62.68	73.87	68.07	43.87
Average Purchased Power (% of Retail Sales):	83.46	N/A	94.56	44.21	91.03
Average Total Revenues per System ($000):	12,065	42,281	42,156	422,752	6,551
Average Net Electric Plant in Service ($000):	40,580,950	211,959,300	541,064,600	757,098,000	15,913,630
Average Monthly Residential Bill (1000 kWh):	$50.84	N/A	N/A	$57.06	$45.81
Average Number of Employees:	63	68	214	1,797	33
Percent of Systems Owning Transmission:	27.53	31.25	9.52	90.00	27.19

Table B-5. Summary Statistics on Public Power Capacity by Generator Type

	Installed Capacity (MW)	Percent of Total Installed Capacity	No. of Utilities	No. of Utilities This Generation Type Only	Median Utility Size (Customers)	Median Size Installed (kW) Capacity	Range of Installed Capacity (kW)
Coal-fired boiler	23,484.4	26.3	123	34	9,407	38,000	33 to 2,324,000
Hydro	18,957.0	21.3	126	66	3,707	2,930	0 to 1,268,399
Dual fuel/ Gas-fired boiler	14,276.3	16.0	106	0	7,404	22,250	175 to 2,400,000
Nuclear	9,986.1	11.2	18	6	59,491	36,205	1,500 to 1,896,000
Oil-fired boiler	9,055.6	10.2	67	26	5,634	15,000	500 to 2,866,900
Combustion turbine	5,643.9	6.3	37	0	27,410	33,600	2,500 to 473,200
Combined cycle	2,799.7	3.1	24	0	22,755	30,000	800 to 414,000
Gas-fired engine	1,668.7	1.9	207	88	1,810	6,340	200 to 40,000
Oil-fired engine	1,109.3	1.2	215	82	1,743	2,400	150 to 59,091
Dual fuel-fired engine	511.1	0.6	18	7	3,480	7,150	500 to 94,320
Geothermal	479.5	0.5	4	0	191,905	63,500	55,000 to 72,000
TOTAL*	89,115.8	100.0	517	309	2,155	9,010	0 to 6,888,750

NOTE: "Total" may not always add due to exclusion of miscellaneous generation; includes joint action agencies.

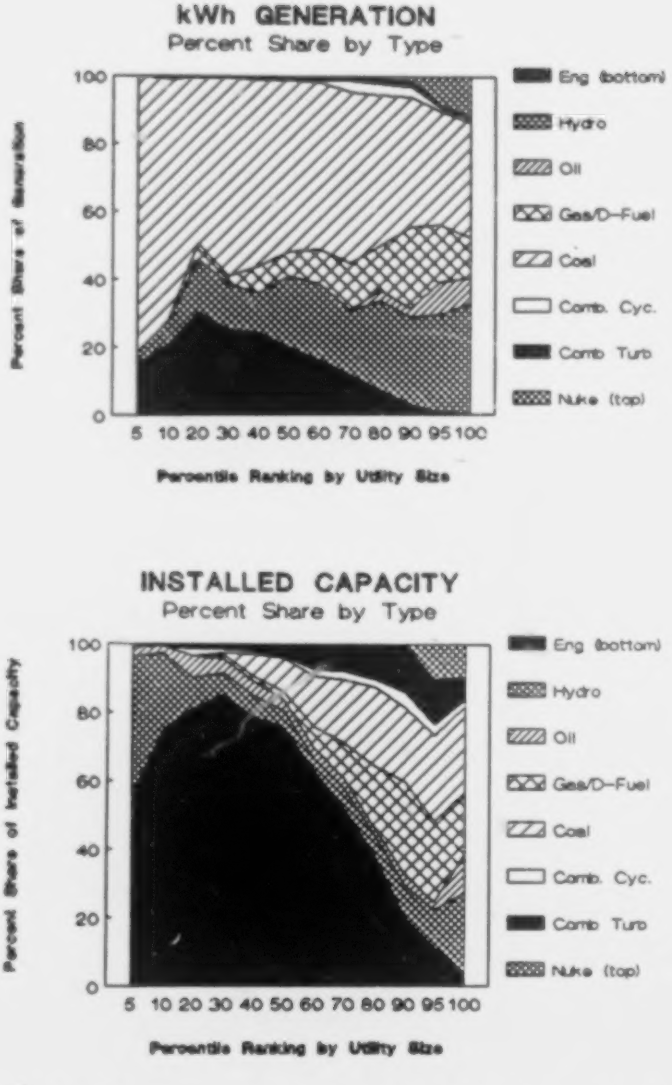
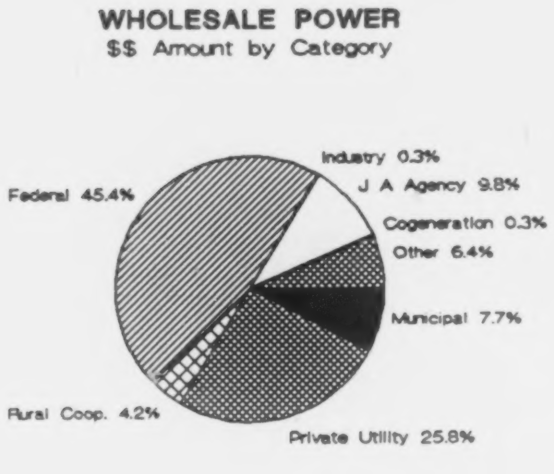


Figure B1. Relative Importance of Generation by Type as a Function of Utility Size, Public Power Generators

Table B-6. Summary Statistics on Public Power Energy Generation by Generator Type

	Installed Generation (GWH)	Annual Generation (GWH)	Percent of Total Generation (%)	Average Capacity Factor (%)*
Coal-fired boiler	23,484.4	99,664.8	36.1	48.6
Hydro	18,957.0	78,404.7	28.4	48.5
Dual-fuel/Gas-fired boiler	14,276.3	28,897.5	10.5	24.1
Nuclear	9,986.1	39,786.1	14.4	44.3
Oil-fired boiler	9,055.6	18,352.0	6.6	19.5
Combustion turbine	5,643.9	944.2	0.3	2.1
Combined Cycle	2,799.7	4,189.9	1.5	17.1
Gas-fired engine	1,668.7	59.2	>0.1	2.9
Oil-fired engine	1,109.3	335.3	0.1	5.2
Dual-fuel fired engine	511.1	840.0	0.3	6.6
Geothermal	479.5	1,092.3	0.4	35.7
TOTAL	89,115.8	276,045.4	100.0	35.4

NOTE: "Total" may not always add due to the exclusion of miscellaneous generation; includes joint action agencies.
*Capacity factor is only calculated for generator types not on standby duty.



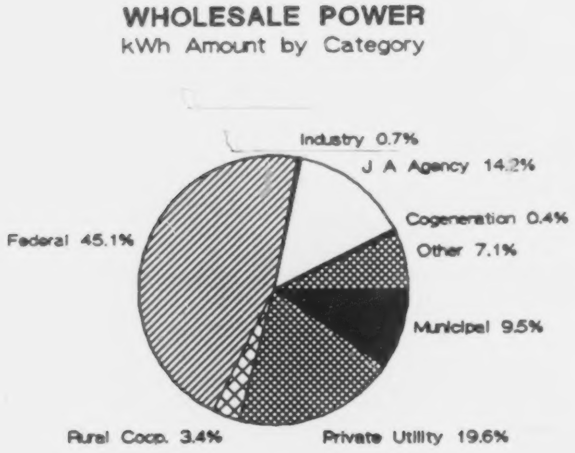


Figure B-2. Source and Relative Importance of Public Power Wholesale Power Purchases by Source

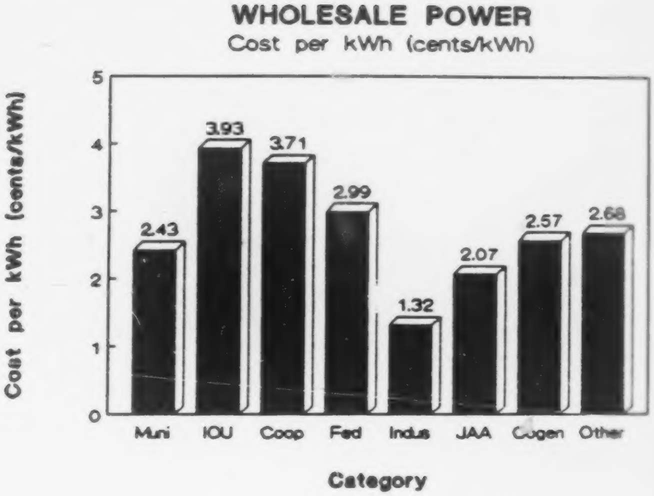


Figure B-3. Comparative Average Price Paid by Public Power for Wholesale Power

Table B-7: Listing of Twenty Largest Retail Public Power Systems

CITY OF HUNTSVILLE UTILITIES
HUNTSVILLE, ALABAMA

SALT RIVER PROJECT
PHOENIX, ARIZONA

CITY OF ANAHEIM
ANAHEIM, CALIFORNIA

LOS ANGELES DEPARTMENT OF WATER AND POWER
LOS ANGELES, CALIFORNIA

SACRAMENTO MUNICIPAL UTILITY DISTRICT
SACRAMENTO, CALIFORNIA

COLORADO SPRINGS DEPARTMENT OF UTILITIES
COLORADO SPRINGS, COLORADO

JACKSONVILLE ELECTRIC AUTHORITY
JACKSONVILLE, FLORIDA

ORLANDO UTILITIES COMMISSION
ORLANDO, FLORIDA

NEBRASKA PUBLIC POWER DISTRICT
COLUMBUS, NEBRASKA

OMAHA PUBLIC POWER DISTRICT
OMAHA, NEBRASKA

CITY OF CHATTANOOGA
CHATTANOOGA, TENNESSEE

CITY OF KNOXVILLE
KNOXVILLE, TENNESSEE

CITY OF MEMPHIS
MEMPHIS, TENNESSEE

CITY OF NASHVILLE
NASHVILLE, TENNESSEE

CITY OF AUSTIN
AUSTIN, TEXAS

CITY OF SAN ANTONIO
SAN ANTONIO, TEXAS

CITY OF SEATTLE
SEATTLE, WASHINGTON

SNOHOMISH COUNTY PUD NO 1
EVERETT, WASHINGTON

CITY OF TACOMA
TACOMA, WASHINGTON

PUERTO RICO ELECTRIC POWER AUTHORITY
SAN JUAN, PUERTO RICO

Table B-8: Listing of Major Joint Action Agencies

ALABAMA MUNICIPAL ELECTRIC AUTHORITY
MONTGOMERY, ALABAMA

CENTRAL CALIFORNIA POWER AGENCY
SACRAMENTO, CALIFORNIA

M-S-R PUBLIC POWER AGENCY
MODESTO, CALIFORNIA

NORTHERN CALIFORNIA POWER AGENCY
ROSEVILLE, CALIFORNIA

SOUTHERN CALIFORNIA PUBLIC POWER AGENCY
GLENDALE, CALIFORNIA

ARKANSAS RIVER POWER AUTHORITY
LAMAR, COLORADO

PLATTE RIVER POWER AUTHORITY
FORT COLLINS, COLORADO

CONNECTICUT MUNICIPAL ELECTRIC ENERGY COOPERATIVE
NORWICH, CONNECTICUT

DELAWARE MUNICIPAL ELECTRIC CORP
NEWARK, DELAWARE

FLORIDA MUNICIPAL POWER AGENCY
ORLANDO, FLORIDA

MUNICIPAL ELECTRIC AUTHORITY OF GEORGIA
ATLANTA, GEORGIA

ILLINOIS MUNICIPAL ELECTRIC AGENCY
DEERFIELD, ILLINOIS

INDIANA MUNICIPAL POWER AGENCY
INDIANAPOLIS, INDIANA

SOUTHERN IOWA MUNICIPAL ELECTRIC COOPERATIVE
WINTERSET, IOWA

WESTERN IOWA MUNICIPAL ELECTRIC COOPERATIVE ASSOCIATION
MANNING, IOWA

KANSAS MUNICIPAL ENERGY AGENCY
MISSION, KANSAS

LOUISIANA ENERGY AND POWER AUTHORITY
LAFAYETTE, LOUISIANA

MASSACHUSETTS MUNICIPAL WHOLESALE ELECTRIC CO
LUDLOW, MASSACHUSETTS

MICHIGAN PUBLIC POWER AGENCY
KENTWOOD, MICHIGAN

MICHIGAN SOUTH CENTRAL POWER AGENCY
LITCHFIELD, MICHIGAN

NORTHEASTERN MINNESOTA MUNICIPAL POWER AGENCY
HIBBING, MINNESOTA

NORTHERN MUNICIPAL POWER AGENCY
THIEF FALLS, MINNESOTA

SOUTHERN MINNESOTA MUNICIPAL POWER AGENCY
ROCHESTER, MINNESOTA

WESTERN MINNESOTA MUNICIPAL POWER AGENCY
ORTONVILLE, MINNESOTA

MUNICIPAL ENERGY AGENCY OF MISSISSIPPI
GREENWOOD, MISSISSIPPI

MISSOURI JOINT MUNICIPAL ELECTRIC UTILITY COMMISSION
COLUMBIA, MISSOURI

NEBRASKA MUNICIPAL POWER POOL
LINCOLN, NEBRASKA

MUNICIPAL ENERGY AGENCY OF NEBRASKA
LINCOLN, NEBRASKA

NORTH CAROLINA MUNICIPAL POWER AGENCY NUMBER 1
RALEIGH, NORTH CAROLINA

NORTH CAROLINA EASTERN MUNICIPAL POWER AGENCY
RALEIGH, NORTH CAROLINA

NORTH DAKOTA MUNICIPAL POWER AGENCY
BISMARCK, NORTH DAKOTA

AMERICAN MUNICIPAL POWER-OHIO
WESTERVILLE, OHIO

OKLAHOMA MUNICIPAL POWER AUTHORITY
EDMOND, OKLAHOMA

PIEDMONT MUNICIPAL POWER AGENCY
GREER, SOUTH CAROLINA

HEARTLAND CONSUMER POWER DISTRICT
MADISON, SOUTH DAKOTA

MISSOURI BASIN MUNICIPAL POWER AGENCY
SIOUX FALLS, SOUTH DAKOTA

SAM RAYBURN MUNICIPAL POWER AGENCY
LIVINGSTON, TEXAS

TEXAS MUNICIPAL POWER AGENCY
BRYAN, TEXAS

INTERMOUNTAIN POWER AGENCY
MURRAY, UTAH

UTAH ASSOCIATED MUNICIPAL POWER SYSTEMS
SANDY, UTAH

UTAH MUNICIPAL POWER AGENCY
SPANISH, UTAH

VERMONT PUBLIC POWER SUPPLY AUTHORITY
WILLISTON, VERMONT

CENTRAL WASHINGTON POWER AGENCY
ELLENSBURG, WASHINGTON

CLARK-COWLITZ JOINT-OPERATING AGENCY
LONGVIEW, WASHINGTON

WASHINGTON PUBLIC POWER SUPPLY SYSTEM
RICHLAND, WASHINGTON

WESTERN WISCONSIN MUNICIPAL POWER GROUP
FENNIMORE, WISCONSIN

WISCONSIN PUBLIC POWER INC SYSTEM
SUN PRAIRIE, WISCONSIN

WYOMING MUNICIPAL POWER AGENCY
LUSK, WYOMING

Table B-9: Listing of Other Public Power Wholesale Suppliers and Joint Action Agencies

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

ARIZONA POWER AUTHORITY
PHOENIX, ARIZONA

CORTARO-MARANA IRRIGATION DISTRICT
MARANA, ARIZONA

ELECTRICAL DISTRICT NO 1
STANFIELD, ARIZONA

ELECTRICAL DISTRICT NO 7
PEORIA, ARIZONA

ELECTRICAL DISTRICT NO 8
PHOENIX, ARIZONA

MARICOPA WATER DISTRICT
WADDELL, ARIZONA

ROOSEVELT IRRIGATION DISTRICT
BUCKEYE, ARIZONA

ARIZONA POWER POOLING ASSOC
BENSON, ARIZONA

CALAVERAS COUNTY WATER DISTRICT
SAN ANDREAS, CALIFORNIA

CALIFORNIA DEPT OF WATER RESOURCES
SACRAMENTO, CALIFORNIA

EAST BAY MUNICIPAL UTILITY DISTRICT
OAKLAND, CALIFORNIA

SAN FRANCISCO PUBLIC UTILITIES
(HETCH HETCHY WATER & POWER DEPT)
SAN FRANCISCO, CALIFORNIA

KINGS RIVER CONSERVATION DISTRICT
FRESNO, CALIFORNIA

MERCED IRRIGATION DISTRICT
MERCED, CALIFORNIA

METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA
LOS ANGELES, CALIFORNIA

OROVILLE-WYANDOTTE IRRIGATION DISTRICT
OROVILLE, CALIFORNIA

PLACER COUNTY WATER AGENCY
FORESTHILL, CALIFORNIA

TUOLUMNE COUNTY PUBLIC POWER AGENCY
SONORA, CALIFORNIA

YUBA COUNTY WATER AGENCY
DOBBINS, CALIFORNIA

SOUTHERN CALIFORNIA UTILITY POWER POOL
LOS ANGELES, CALIFORNIA

TRANSMISSION AGENCY OF NORTHERN CALIFORNIA
SACRAMENTO, CALIFORNIA

NORTHERN IOWA MUNICIPAL ELECTRIC COOPERATIVE ASSOCIATION
HUMBOLDT, IOWA

MISSOURI BASIN MUNICIPAL ELECTRIC COOPERATIVE ASSOCIATION ORANGE CITY, IOWA

CITY OF OPELOUSAS
OPELOUSAS, LOUISIANA

SABINE RIVER POWER AUTHORITY
BATON ROUGE, LOUISIANA

CITY OF LEWISTON
LEWISTON, MAINE

DIRIGO ELECTRIC COOPERATIVE INC
AUGUSTA, MAINE

MONTANA BOARD OF NATURAL RESOURCES
HELENA, MONTANA

COLORADO RIVER COMMISSION OF NEVADA
LAS VEGAS, NEVADA

LINCOLN COUNTY POWER DISTRICT
PIOCHE, NEVADA

MINERAL COUNTY POWER SYSTEM
HAWTHORNE, NEVADA

LONG ISLAND POWER AUTHORITY
MINEOLA, NEW YORK

NEW YORK POWER AUTHORITY
NEW YORK, NEW YORK

GRAND RIVER DAM AUTHORITY
VINITA, OKLAHOMA

BRAZOS RIVER AUTHORITY
WACO, TEXAS

GUADALUPE-BLANCO RIVER AUTHORITY
SEGUIN, TEXAS

TRINITY RIVER AUTHORITY
ARLINGTON, TEXAS

JEFFERSON COUNTY PUD NO 1
PORT TOWNSEND, WASHINGTON

WHATCOM COUNTY PUD
BELLINGHAM, WASHINGTON

WEST VIRGINIA PUBLIC ENERGY AUTHORITY
CHARLESTON, WEST VIRGINIA

BADGER POWER MARKETING AUTHORITY
SHAWANO, WISCONSIN

APPENDIX C:

APPA RESOLUTION ON FUEL CELL COMMERCIALIZATION

88-12

FUEL CELL COMMERCIALIZATION

WHEREAS, many local publicly owned electric systems seek cost-effective and acceptable methods to control future power supply, and

WHEREAS, ownership of self-generation by public power systems is an important factor to secure such power supplies as well as to improve the ability to negotiate purchased power supplies, and

WHEREAS, fuel cell powerplants promise superior environmental performance, high efficiencies, acceptable costs, cogeneration potential and flexible operation, in a size appropriate to the requirements of public power, and

WHEREAS, because of the unique fit of fuel cell technology to the requirements of local publicly owned electric systems, public power represents a critical market for multi-megawatt fuel cells, as has been reflected in the leadership by a set of public power systems to promote the commercial readiness of the technology, and

WHEREAS, successful commercial development of fuel cells requires the demonstration of the technology through a partnership that may involve manufacturers, various segments of the electric utility industry, and concerned agencies of government;

NOW, THEREFORE, BE IT RESOLVED: that the American Public Power Association shall:

1. Support the commercial development of multi-megawatt fuel cell power plants;
2. Communicate public power's commitment to the fuel cell option to any party in a position to promote its commercial availability;
3. Continue to seek financial support to demonstrate fuel cell power plants from appropriate entities, including, but not limited to, manufacturers of fuel cell equipment, the Electric Power Research Institute, interested public power systems, the Congress, and appropriate agencies of government; and
4. Keep its membership informed on a timely basis of the opportunities to promote fuel cell development and the status of the technology's commercial readiness.

-- Adopted June 26, 1988, by the membership of the American Public Power Association at its annual conference in Seattle, Washington.

APPENDIX D:

THE UNIQUE BENEFITS OF FUEL CELLS

THE UNIQUE BENEFITS OF FUEL CELLS

Fuel cells offer advantages in efficiency, reliability, economy, cleanliness, unique operating characteristics, planning flexibility, and future development potential. APPA's understanding of these benefits is summarized below.

Fuel Cells Offer High Efficiencies and Reliability

The fuel cell can convert up to 80% of the energy from its supply fuel into useable electric power and heat. Current phosphoric acid fuel cell (PAFC) designs offer 41% electrical conversion efficiency on a high-heating value basis, with 46% electrical conversion efficiencies for PAFC possible in the near-term through currently known science and engineering. The Electric Power Research Institute has estimated that advanced molten carbonate fuel cells (MCFC) may achieve electric efficiencies greater than 60%, exclusive of a topping cycle which would raise efficiencies even higher. Such efficiencies are unprecedented. Furthermore, a fuel cell's efficiency is largely independent of its size. Fuel cells can operate at half their rated capacity while maintaining high fuel-use efficiencies.

Fuel cell power stations located close to loads can also reduce costly transmission lines and transmission losses.

Another important attribute of the fuel cell is its ability to cogenerate: that is, to produce hot water and lower-temperature steam at the same time it generates electricity. Its ratio of electric to thermal output is approximately 1.0, while for a gas turbine the ratio is about 0.5. This advantage means that a fuel cell matched to a thermal load will have approximately twice the electric output of a combustion turbine matched to that same load. In smaller sizes of interest to most public power systems, fuel cells are also more efficient (by about a factor of two) when compared to, for example, the 15,000 Btu/kWh heat rate of a 2-MW combined cycle system. The fuel cell's load following capability, while maintaining high efficiency, may also give it an advantage in cogeneration markets with varying heat demands.

Fuel cell systems should have higher reliability than combustion turbine-combined cycle systems or internal combustion engines because they contain fewer moving parts. Fuel cells will not experience catastrophic failure as a combustion turbine or internal combustion engine will when rotating parts fail; they experience only a gradual loss of efficiency. Mature fuel cell systems are expected to have higher availabilities than competing technologies.

Fuel Cells Have Unparalleled Environmental Performance

Substitution of fuel cells for conventional power plants should improve air quality and reduce water consumption and wastewater discharge. The generation of electricity now produces more particulates, sulfur oxides and nitrogen oxides than all other stationary sources combined. Fuel cell power plant emissions are ten times lower than those specified by the most stringent environmental regulations. Fuel cells also produce lower carbon dioxide (CO_2) emissions than conventional generation, a question of increasing concern due to the so-called "greenhouse effect."

Because the electrochemical reaction of the fuel cell produces water as a byproduct, little if any external water is required for power plant operation. This low water use is in marked contrast to large steam electric power plants that require massive quantities of water for cooling. Wastewater discharges from fuel cell systems are also lower and the quality is superior compared with conventional fossil-fueled power plants, requiring no pretreatment prior to disposal in many communities. Fuel cells eliminate or reduce water quality problems associated with thermal discharges, powerplant site runoff, and the disposal of wastes from air emission controls.

The quiet, electrochemical nature of fuel cells eliminates many of the sources of noise associated with conventional steam-powered systems, thus easily complying with OSHA (Occupational Health and Safety Administration) standards. No ash or large volume wastes are produced from fuel cell operation. Land requirements are acceptable, and connecting transmission corridors are not required as is the case with outside power sources. Because of their comparatively small size, absence of a combustion cycle, state-of-the-art safety systems, and low pollutant emissions, fuel cells are among the least hazardous methods of energy conversion.

Fuel Cells Have Unique Operating Characteristics

Fuel cells have beneficial operating characteristics matched by no other technology. These characteristics save costs in meeting system operating requirements. Dynamic operating benefits include load following, power factor correction, quick response to generating unit outages, and control of distribution line voltage and quality control.

The power conditioner unit of the fuel cell power station can be used to control real and reactive power independently. Control of power factor and line voltage to meet load can minimize transmission losses and reduce requirements for reserve capacity and auxiliary electrical equipment such as capacitors, tap-changing transformers, and voltage regulators.

When new generating capacity is added to an electric power system, substation equipment sometimes has to be upgraded because of the expectation of increased fault current (which lowers the reliability of the electric system). However, with fuel cell power units, it is not necessary to upgrade the fault-current interrupting capability of existing substation equipment, because the fuel cell power units have a short-circuit ratio of about 1:1. The fuel cell also controls disconnect if it is necessary.

Fuel cells can easily regulate deviations from system frequency on an area-by-area basis. This benefit leads to an increase in overall system stability and overcomes the present fuel penalties that result from the need to switch to other (often oil-fired) generating units to meet the deviations in frequency caused by localized variations in load in the system.

Fuel cell units have an excellent part-load heat rate and can respond rapidly to transient loads. For example, the heat rate of a phosphoric acid demonstration unit is anticipated to be 8,300 Btu/kWh at rated power and to increase slightly at 50% of rated capacity. Also, it is expected to be able to go from 30% of rated power to rated power in only 7 seconds. Spinning reserve requirements can thus be lessened when fuel cells are used.

One of the recurring problems facing energy control dispatchers is how to operate the system during periods of high load pickup, so there is sufficient generation to follow the load pickup, while still maintaining reserve or regulating margin. Dispatchers typically meet this "regulatory margin" by loading more expensive units above their economic assignment early in the load pickup period. The cost penalty for these inefficiencies can be overcome by keeping fuel cells on-line longer and using their high part-load efficiencies.

Fuel cell power plants are also designed for unattended operation.

Fuel Cells Provide Planning Flexibility

Planning flexibility, including modularity, results in strategic and financial benefits to the utility and its customers. Because fuel cell power plants may be built within two years of order, and because performance is largely independent of plant size, they can be used to increase utility system capacity by small increments in response to customer needs.

By better matching increases in electric demand, long periods of overcapacity are avoided, lowering average fixed costs over time. And, if demand growth is uncertain, the fuel cell's short lead time becomes even more valuable. A utility can slow or accelerate its response to growth. Also, as experience is gained with fuel cells, utilities may be able to reduce required reserve margins while maintaining the same reliability, resulting in lower fixed costs.

The community benefits from the increased reliability from smaller units distributed throughout the grid. And, placing generation at the distribution level reduces the likelihood of outages due to external transmission interruptions.

Though initial fuel cells will be designed to be fueled with either natural gas or naphtha (a widely available, low-cost refinery product), the cells require hydrogen. The so-called reformer that produces this hydrogen-rich gas allows the use of a variety of low-sulfur gaseous and liquid fuels. Advanced fuel cells should also be able to operate on gasified coal.

These planning flexibilities are not all unique to fuel cells. Combined-cycle units and internal combustion engines each share some of these flexibilities. But combined with their other advantages, fuel cells are truly a unique energy resource.

Fuel Cells Have Future Potential

The potential of fuel cells to break through the efficiency barriers now being met by all conventional generation cannot be overemphasized.

As a developing technology, the phosphoric acid fuel cell should see significant efficiency improvements. Over the next 15 to 20 years, more advanced fuel cell designs based on molten carbonate or solid oxides may be able to demonstrate quantum leaps in efficiency improvements.

The fuel cell's competitors, on the other hand, including gas turbines and internal combustion engines, are at a mature stage of development. Small incremental improvements are the most that can be expected from these technologies. And improvements in conventional technologies will come at the expense of higher operating temperatures and, therefore, greater nitrogen oxide air pollution.

APPENDIX E:

PRELIMINARY RESULTS FROM APPA'S "PUBLIC POWER FUEL CELL MARKET STUDY"

PRELIMINARY RESULTS FROM APPA'S "PUBLIC POWER FUEL CELL MARKET STUDY"

Figure E-1 presents the maximum market size in which fuel cells will be competing, among individual retail systems that are not members of a joint action agency. This maximum market is defined as the combination of the three market segments:

1) Replacement of existing purchased power controls (see Section II);

2) Replacement of retired capacity;

3) Additions to meet load growth requirements.

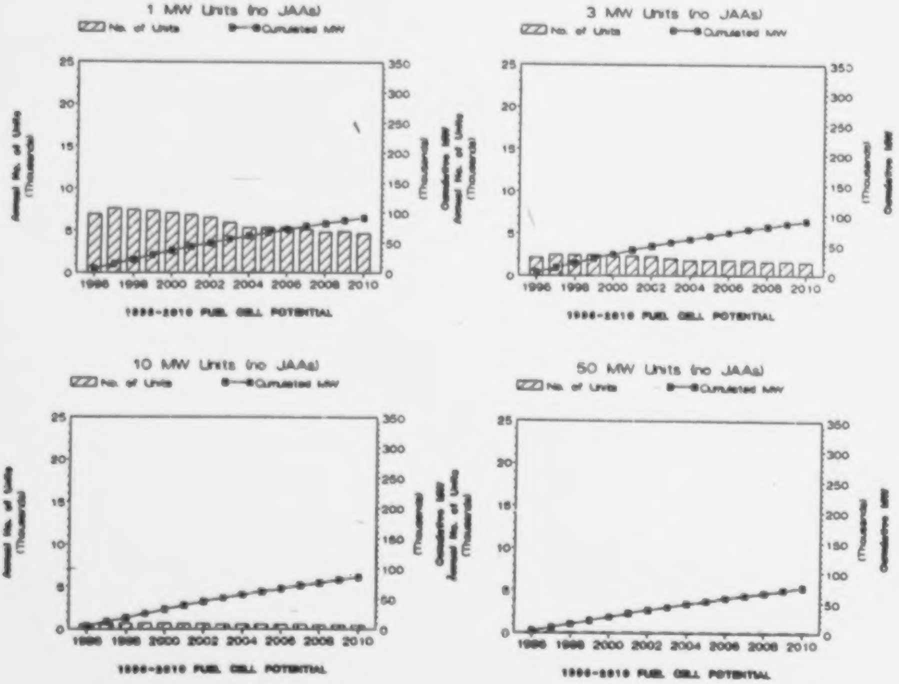


Figure E-1. Maximum 1996-2010 Potential Market for Four Different Unit Sizes, Individual Retail (non-JAA) Systems Only.

Each utility, its load growth, purchased power, exiting capacity, and maximum depending on a single resource are considered separately.

No consideration of fuel cell price, its competition or market penetration limitations in the early years is included in this step or in further results presented in this NOMO. These will be considered in the market study report to be issued in December 1988.

Figure E-2 presents the maximum market size in which fuel cells will be competing, for all retail public power systems including joint action agencies.

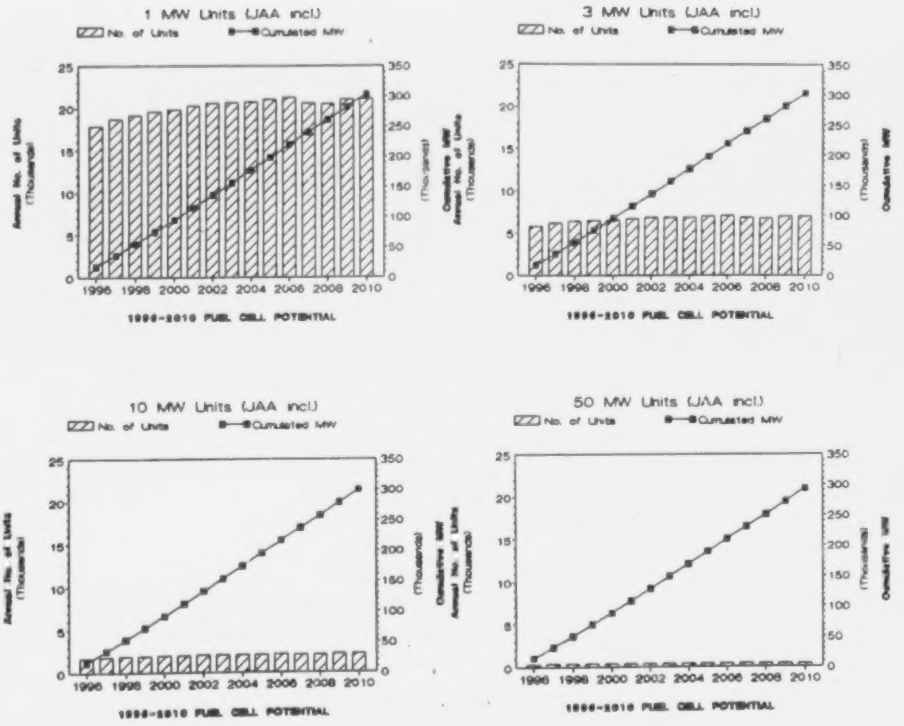


Figure E-2. Maximum 1996-2010 Potential Market for Four Different Unit Sizes, Joint Action Agencies and Non-Agency Member Retail Systems

Figure E-3 presents the maximum "likely early" market in which fuel cells will compete, among all retail public power systems. This "likely early" market is defined as those systems that already own at least some of their own generating capacity presently face environmental constraints, and have a rate advantage in comparison with their neighboring private power system.

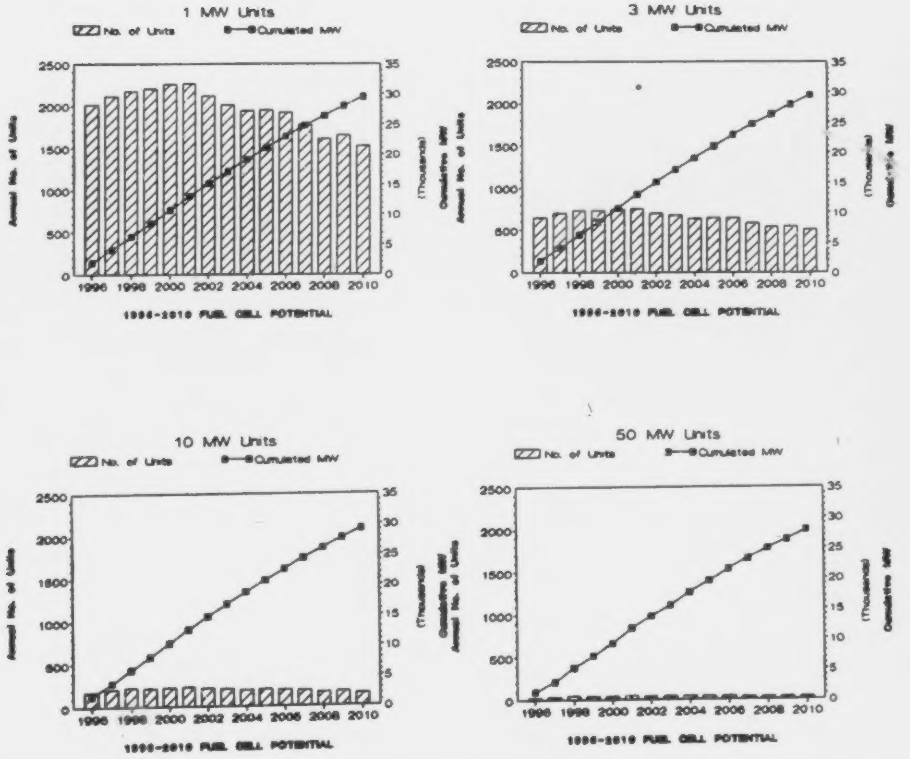


Figure E-3. Maximum 1996-2010 Potential "Likely Early" Market, for Four Different Unit Sizes

Figure E-4 presents the maximum "potential early" market among retail public power systems with environmental (air or water) constraints, and a competitive rate advantage over the neighboring private or cooperative utility. Existing generation is not a pre-requisite.

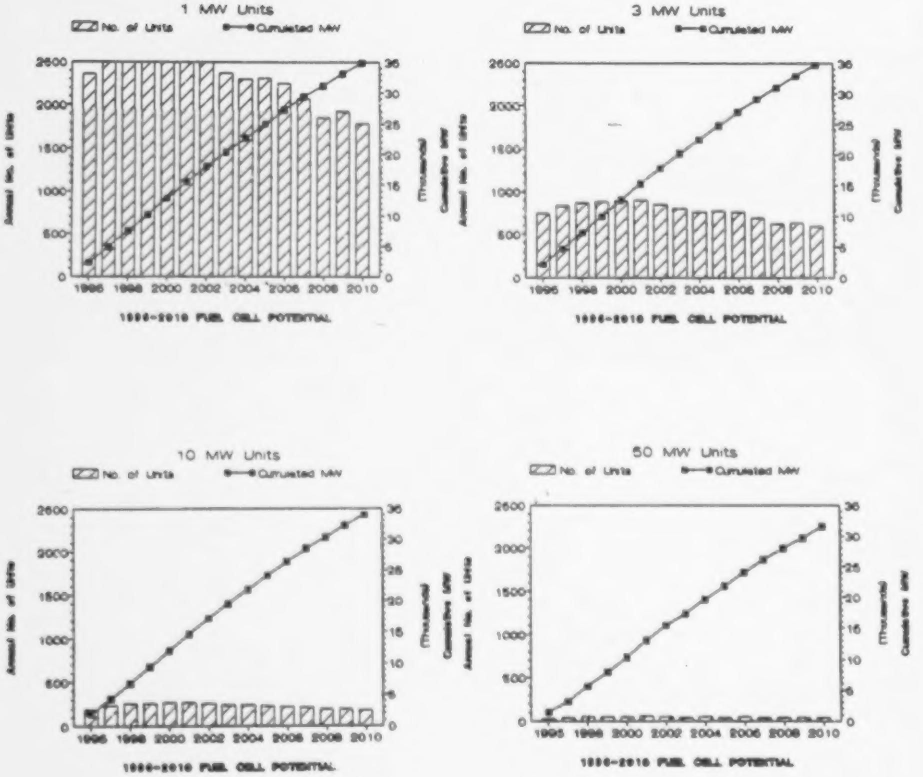


Figure E-4. Maximum 1996-2010 "Potential Early" Market, for Four Different Unit Sizes

Figure E-5 presents the maximum "potential early" market among small public power systems with environmental constraints and a competitive rate advantage over the neighboring private utility. This market excludes the largest 20 retail systems to show the potential for the smaller but typical public power systems.

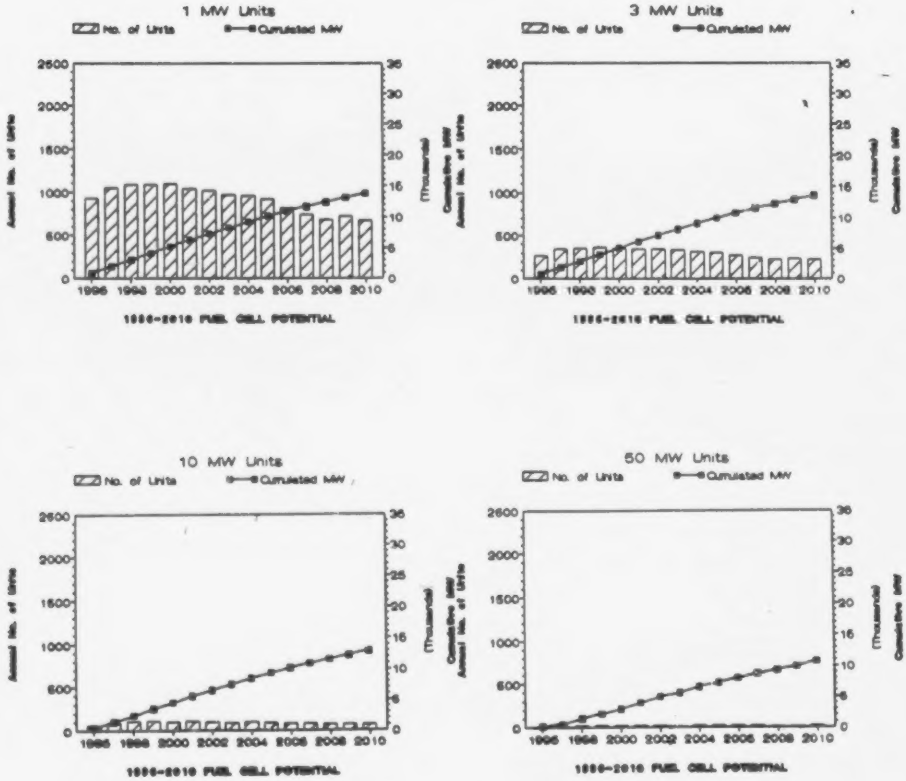


Figure E-5. Maximum 1996-2010 "Potential Early Market Among Small Public Power Systems," for Four Unit Different Sizes

Table E-1. Comparative Totals for Potential Public Power Fuel Cell Markets

	All of Public Power	"Likely, Early" Market	"Potential, Early" Market	"Potential, Early" Market (Small)
Hourly System Peak (MW) =	90,149,900	24,180,1002	8,018,300	11,519,300
Number of Residential Customers =	12,117,000	4,115,000	4,813,000	1,926,171
Number of Commercial Customers =	1,579,720	519,415	599,319	248,268
Number of Industrial Customers =	108,424	41,765	49,205	17,650
Number of Other Customers =	286,937	69,385	81,239	35,074
Number of Customers -- Total Retail Sales =	15,277,050	4,786,881	5,673,711	2,332,745
Number of Resale Sales Customers =	1,813	169	577	530
Number of Meters Served =	15,220,250	4,787,050	5,674,288	2,333,275
Residential MWh Sales =	116,324,700	36,603,760	43,636,390	17,077,180
Commercial MWh Sales =	81,723,030	30,982,830	35,169,180	13,476,880
Industrial MWh Sales =	116,333,600	34,103,020	38,967,000	19,062,230
Other MWh Sales =	26,585,510	4,331,929	4,836,057	1,939,987
Total Retail MWh Sales =	506,350,600	106,164,200	124,116,400	53,064,000
Resale MWh Sales =	145,753,800	15,567,590	15,603,800	7,222,870
Total Sales MWh Sales =	652,322,200	121,731,800	139 ,720,200	60,286,870
Residential Revenues ($000) =	7,008,697	2,098,911	2,501,640	946,156
Commercial Revenues ($000) =	6,506,854	1,855,967	2,113,367	791,092
Industrial Revenues ($000) =	5,172,782	1,550,210	1,794,507	870,244
Other Revenues ($000) =	1,425,049	197,932	227,362	108,031
Retail Sales Revenues ($000) =	20,114,080	5,703,021	6,636,875	2,715,523
Resale Revenues ($000) =	4,144,879	426,534	428,734	213,388
Total Sales Revenues ($000) =	25,327,700	6,135,073	7,153,093	3,016,396
Net Electric Plant in Service ($000) =	39,038,900	12,267,740	12,856,700	3,617,667
Total Net Electric Plant Investments ($000) =	52,719,040	13,926,440	14,564,390	3,727,530
Number of Full-Time Employees =	79,945	26,106	28,539	11,419
Amount of Power Purchased -- Federal Agency (MWh) =	119,956,000	24,056,120	29,933,410	15,735,000
Amount of Power Purchased -- Investor Owned (MWh) =	65,634,780	12,592,930	18,164,920	11,420,860
Amount of Power Purchased -- Cooperative (MWh) =	10,710,260	1,006,572	2,100,028	1,863,360
Amount of Power Purchased -- Municipal (MWh) =	26,095,590	6,604,312	7,684,768	4,563,676
Amount of Power Purchased -- Industry (MWh) =	2,413,790	464,029	568,974	568,962
Amount of Power Purchased -- Cogeneration (MWh) =	1,042,775	136,947	250,878	137,454
Amount of Power Purchased -- Other (MWh) =	20,013,250	1,101,049	1,896,066	1,406,790
Amount of Power Purchased -- Total (MWh) =	422,610,700	51,724,450	73,102,190	46,468,350
Amount of Energy Obtained through J.A.A. (MWh) =	43,884,000	5,651,874	10,878,620	9,147,729
Total Nameplate Generating Capacity (MW) =	89,116	28,643	28,769	8,569
Total Electricity Generating During Year (MWh) =	354,912,700	78,814,660	78,814,660	21,297,710
Capacity Steam Turbine -- Total (MW) =	48,374	17,640	17,715	6,002
Capacity Steam Turbine -- Oil (MW) =	9,056	5,309	5,320	185
Capacity Steam turbine -- Coal (MW) =	23,484	8,551	8,614	4,389

Capacity Steam Turbine -- Gas (MW) =	9,358	2,095	2,095	773
Capacity Steam Turbine -- Dual-fuel (MW) =	4,918	1,614	1,614	655
Capacity Steam Turbine -- Geothermal (MW) =	480	72	72	0
Capacity Nuclear Steam Turbine -- Total (MW) =	9,986	1,487	1,487	16
Capacity Gas Turbine -- Total (MW) =	5,644	2,378	2,386	1,350
Capacity Combustion Engine -- Total (MW) =	3,289	400	441	346
Capacity Hydro -- Total (kW) =	18,957	5,921	5,924	453
Capacity Cogeneration -- Total (kW) =	927	553	554	220
Total Circuit Miles =	59,110	13,554	14,447	6,000

Table E-2. Comparative Averages for Potential Fuel Cell Markets

	All of Public Power	"Likely, Early" Market	"Potential, Early" Market	"Potential, Early" Market (Small)
Number of Systems:	2,092	75	203	193
Average System Peak Demand (MW):	68.1	322.4	165.8	72.8
Average Annual Load Growth (%):	4.00	3.44	3.58	3.19
Average Load Factor (%):	61.63	57.47	56.29	58.19
Average Annual Total System Sales (MWh):	311,818	1,623,091	688,277	312,367
Percent System Sales by Class:				
Residential:	23.90	30.10	31.57	29.05
Commercial:	16.79	25.48	25.45	22.93
Industrial:	23.90	28.05	28.19	32.43
Other Retail:	5.46	3.56	3.50	3.30
Resale:	29.95	12.80	11.29	12.29
Average Number of Total Customers:	7,148	63,827	27,877	12,011
Percent Total Customers by Class:				
Residential:	85.97	86.71	86.82	86.46
Commercial:	11.21	10.94	10.81	11.14
Industrial:	0.77	0.88	0.89	0.79
Other Retail:	2.04	1.46	1.47	1.57
Resale:	0.01	0.01	0.01	0.02
Average Generating Capacity per System (MW):	42	382	142	44
Average Generation per System (MWh):	169,651	1,050,862	388,250	110,351
Average kWh Generation per kW of Capacity:	4,015	2,752	2,740	2,487
Average Self-Generation (% of Total Sales):	54.41	64.74	56.41	35.33
Average Purchased Power (% of Retail Sales):	83.46	48.72	58.90	87.57
Average Total Revenues per System ($000):	12,065	81,801	35,207	15,598
Average Net Electric Plant in Service ($000):	40,580,950	170,385,300	84,030,730	25,298,370
Average Monthly Residential Bill ($/1000 kWh):	$50.84	$61.20	$60.71	$56.72
Average Number of Employees:	63	348	164	70
Percent of Systems Owning Transmission:	27.53	76.00	48.77	46.11

APPENDIX F:

FUEL CELL CHARACTERISTICS OF INTEREST

FUEL CELL CHARACTERISTICS OF INTEREST

Preliminary analysis of the public power fuel cell survey was completed prior to formulation of the larger database being utilized in the market study. Several questions in the survey dealt with issues and factors which are important to fuel cell purchase considerations and fuel cell design.

The most important power supply issues identified by the 200+ survey respondents are ranked below, as well as those of the "most interested respondents" as identified by a respondent's interest in participating in a utility-specific fuel cell evaluation.

Table F-1. Ranking of Most Important Issues in Developing Future Power Supply Plans

	All Respondents	More Interested Respondents
Transmission access	1	9
Transmission capacity or stability	2	7
Operating flexibility of generating units	3	1
Availability of trained personnel	4	8
Fuels availability	5	3
Air quality restrictions	6	2
Uncertainty in future costs of wholesale power	7	6
Efficient generating capacity in small units	8	4
Long term contract availability of wholesale power supplies	9	12
Participation in joint action agency	10	11
Multi-fuel capabilities for generating units	11	5
Possible acid rain legislation	12	15
Site availability/limitations	13	10
Water availability	14	13
Potential for integrating cogeneration with other municipal services	15	14

Several questions in the survey provided information more specifically on fuel cell characteristics of interest. The following tables provide the preliminary results of certain questions.

Table F-2. Preferred Characteristics: Unit Size

Size (MW)	All Respondents %	More Interested Respondents %
1-3	11	10
3-5	25	29
5-8	15	12
8-11	23	31
>11	26	17

Table F-3. Preferred Characteristics: Cold Start-up

Time	All Respondents %	More Interested Respondents %
<3 hours	70	No Significant Difference
3-5	22	
5-6	2	
6-8	6	

Table F-4. Preferred Characteristics: Overnight Standby

Response	All Respondents %	More Interested Respondents
Necessary	11	No Significant Difference
Preferred	60	
Not essential	29	

Table F-5. Preferred Characteristics: Standby-to-Load

Time	All Respondents %	More Interested Respondents
5-10 min.	40	No Significant Difference
10-20	26	
20-30	18	
30 min.- 1hr.	13	
>1hr.	4	

Table F-6. Preferred Characteristics: Partial Load Performance
Maintains full load heat rate down to . . .

% of full load	All Respondents %	Most Interested Respondents %
10-20	20	19
20-30	38	47
30-40	42	34

Table F-7. Ranking of Most Important Fuel Cell Benefits

	All Respondents	More Interested Respondents
Environmentally benign	1	3
High overall efficiencies	2	1
High part load efficiency	3	2
Load following capability	4	5
Short construction times	5	6
Prospects for future efficiency	6	7
Urban siteability	7	8
Low noise levels	8	14
Unattended operation	9	13
High unit availability	10	4
Rapid (1 MW/sec) response	11	9
Reactive power compensation	12	10
Decreased T&D losses due to siting near loads	13	15
Modular nature	14	12
Low water use	15	11

PANEL 1 DISCUSSION

Mrs. **Lloyd**. Thank you very much.

Certainly, we knew that our budget hearings would be a little bit painful, but it's always painful when you see that we have the leading edge on a technology and we take it to the point of criticality, of marketing, and see our funding decrease. We've seen this over the years through this Research and Development Subcommittee.

So certainly there's been a lot of talk about more funding in the demonstration area of our R&D budget.

Why can't the private sector fund the demonstration?

Mr. **Parker**. I'm not a manufacturer. The gentleman next to me is. But our Association could give certainly a perspective on that. These are high-risk technologies which cost a lot of money to bring to demonstration situation.

But demonstration in and of itself involves a number of multiple parties. It involves a host site of designers to do something to integrate it into the host site, plus the manufacturer.

So it's a complex situation requiring coordination, if you wish, of a number of different actors. And that process in itself almost suggests that there should be a joint funding arrangement where the host needs some assurance of reliability, as you've heard before.

So that would be my response to that.

Mrs. **Lloyd**. Would you gentlemen suggest that we review some of our R&D budgets to provide more funding for demonstration?

Are we at the point where we're going to have to cut back on our R&D funding and put more of this money into demonstration to address the problem of taking a technology to the demonstration phase and then, at this point, losing our market to our competitors?

Mr. **Bergman**. My comment on that would be that even during the hay-day of Federal Energy funding in the late 1970s, we have not had a good track record in bringing advanced energy technologies to market. I think one of the key reasons for that perhaps is that much of the funding advocacy has been coming from the developers of those technologies and perhaps not enough from the market.

Insofar as there are available monies that could go to demonstration, as we indicated in our testimony, if those funds could be made available, such as through the cooperative ventures for R&D, I think COLA is a good example, where the markets themselves in tandem with the manufacturer that they selected and are confident can deliver, I think would offer the best prospect that those limited dollars would be devoted, where they could best be spent.

Mr. **Parker**. I would like to support the statement of Mr. Bergman. I've been around this business for a long time dealing with some of the much earlier demonstration programs that he's referring to. And the problem from our perspective, associated with those programs, is that they were not directed in the manner that was just explained.

And there's no reason why demonstrations couldn't be very effective and very beneficial.

Mrs. LLOYD. When we look at our Clean Coal technology program, we're looking at $2.5 billion. So that's taking the bulk of our coal funding.

Mr. SCHORA. Madam Chairman, we attempted to bid on Clean Coal II. We submitted a proposal using our concept. That proposal was not accepted. I think one of the problems here is that the definition possibly under which the acceptance of Clean Coal programs is going forward would preclude the introduction of fuel cells in that program.

And until those are changed to basically accept those somewhat more innovative but potentially lower investment and higher efficiency systems, Clean Coal II is a rather frustrating approach for us.

Mrs. LLOYD. Thank you.

Mr. Morrison.

Mr. MORRISON. I'd like to concentrate, too, on this demonstration gap that is such a common thread through so many things that this Subcommittee deals with.

You say you were frustrated by this No. 2, the possibilities. Why were fuel cells left out of this opportunity? Was the driver the Department of Energy? Was the driver the Coal Association?

Who were the guilty parties?

Mr. SCHORA. Well, from my standpoint, they weren't excluded from his invitation to bid. However, there were two dilemmas that I think arose that we gained from insight into some of the debriefings and some post-discussions.

One of them was basically that the fuel cell can be modular in nature and can be adequately demonstrated at a level of, say, two-five megawatts, or even smaller, because they are a module and can be built on.

So that's a very efficient way to demonstrate the technology. However, the gasifier which must go along with the fuel cell is relatively small at that size. And because we could not demonstrate a gasifier at commercial size along with the fuel cells, we were downgraded significantly in our evaluation.

I think another point is that in the definition of what is acceptable for Clean Coal programs, there is a time frame that these technologies must be commercially utilized, before or around the year 2000. I think fuel cells possibly go a little bit just beyond that.

And for that reason, I don't think they were given a fair test in the evaluation.

Mr. BERGMAN. And the requirement that the system be based on coal adds to the already fairly large technical risk of demonstrating a fuel cell at scale.

Optimally, demonstration of a fuel cell at large scale would be natural gas base and then you would evolve into a coal based gasifier.

Bundling both of those together made it quite difficult for them.

Mr. MORRISON. That makes all kinds of sense to me. And I'm a little frustrated by this because the Department has consistently bailed out just a little before the point where we provided the incentives to get you to the marketplace.

And that's where of course our competitors overseas jump in it and specialize very, very well.

Mr. Bergman, having worked with your Association through the years on a variety of things, I would agree with your comments that, as a users group representative, you maybe have the best potential for coordinating, filling in part of that link if you had some cash incentives along the way.

What—just one question—what reduction in carbon dioxide emissions can we achieve through cells?

Mr. **Schora**. Well, as I had mentioned this morning in the testimony, we can see with a coal based system a reduction equivalent to an existing power plant of about 42 percent reduction in CO_2.

If one were to operate these cells on natural gas, where you can achieve efficiencies in excess of 60 percent, then it is very significant.

Mr. **Bergman**. Furthermore, if you cogenerate with fuel cells, which will likely be because of the higher initial cost, likely be the application that will have to be looked at for early commercialization, you're in essence getting twice the useful energy delivered for the input.

And because of their smaller scale, it can be cited close to users of waste heat. So, there, you're also gaining a benefit from a carbon dioxide point of view.

Mr. **Parker**. These last couple of points of Mr. Bergman's I'd just like to reinforce. They're very, very important points. Fuel cells have this potential to be co-located. When you're talking about cogeneration, you're talking about efficiencies in the range of 80 percent.

So I mean these are real; these are not fictitious numbers.

When you also look at the Clean Coal program, and the reason we addressed the total budget, is fuel cells are coupled nicely to, as has already been said, natural gas or possibly methanol or hydrogen as a direct input fuel.

And so you don't need coal gasifiers and what have you to get started.

Mr. **Morrison**. Well, this is an exciting technology. I'm almost inclined to say, if there was one area we were going to pick to fill, to come up with some new magic formulas on filling that demonstration gap, it would be in this particular technology.

So thank you very much for your input.

Mr. Chairman, thank you.

Mr. **Boucher** [presiding]. Thank you, Mr. Morrison.

Mr. Schora, let me ask you a little bit about your molten technology, molten carbonate technology.

You had applied I think in the second round of solicitations for the Clean Coal technology reserve for funding of that technology.

Mr. **Schora**. Yes, sir.

Mr. **Boucher**. I think you were turned down at that time.

Do you intend to apply again in the third round of solicitations? And if you do, have you done anything in the meantime to improve the technology to enhance your prospects of receiving funding?

Mr. **Schora**. Well, the technology is moving forward. We're trying to gear up to manufacture the commercial size cells and stacks that would be necessary for that demonstration.

However, I am somewhat hesitant in going after the so-called Clean Coal III on the basis that I don't think the ground rules have changed. In other words, they're still receiving technology which could be used in the near-term, which has a relatively low chance of meeting any kind of technical difficulty and scale-up. Basically, technology which industry I think on its own might go forward with.

Fuel cells I think lay a little bit beyond the time frame which I think the Department of Energy finds acceptable for successful bidders in this program.

By the way, in our submission, we did have 50 percent of the funding requirements, so from that regard, there was a lot of support from industry and from our partners in the program.

Mr. **Boucher**. Mr. Parker, let me ask you a sort of a broad-brush question.

I notice that the Administration is recommending something on the order of $6 million—$6.5 million—for FY-90 for fuel cell development.

Have you a figure for what an appropriate level of funding would be? And can you tell me what you think the appropriate mix between public and private funding for fuel cell development should be?

Mr. **Parker**. Good question. Thank you.

In both the oral statement and the written statement, I did give a specific breakdown by program area, if you wish, and all DOE, the $44.6 million.

Would you like me to recount that? But it was a broad-brush——

Mr. **Boucher**. If you can do so in some reform, I think it would be helpful.

Mr. **Parker**. Phos-acid technology, $6 million; Molten Carbonate, $20 million; Advanced Concepts, $6 million; Advanced Programs and Technology Development, $1.5 million; cross-cut programs, $2.5 million.

That would be the fossil energy portion, which amounts to $36 million. In addition to that, there is already an active transportation conservation program, the bus limo program. We're recommending $3.6 million there, too, to continue the program in the Phase II; another $1.6 million for other program needs related at advanced concepts for transportation uses.

The energy storage program, which is really a basic research kind of a program, $3 million. And, that, again, would primarily be supporting the proton exchange membrane of fuel cell component technology. And conservation and renewable, we feel $2 million because it addresses a different sector. It's commercial/industrial sector.

Mr. **Boucher**. We have I think a summary of each of these dollar amounts, so let me just ask you a couple of policy questions.

Mr. **Parker**. Well, your question though——

Mr. **Boucher**. Yes, what is in your opinion an appropriate breakdown between the public and private sector in terms of funding?

I guess we could begin by asking how much the private sector is contributing today.

Mr. **Parker**. Good enough. Between 1976 and 1989, according to my figures, the federal government, DOE, primarily, has put in $438 million. And I think Mr. Bergman supported that number just a few minutes ago.

And parallel to that, the numbers that we have for the private sector were $447 million. So it's running roughly 50/50. And I would expect that it would continue to run at least at that level.

I think Mr. Schora just also supported that 50/50 break.

Mr. BOUCHER. Well, we've spent close to $900 million. Slightly over 900 million.

Mr. PARKER. That's correct.

Mr. BOUCHER. Well, not quite $900 million on this technology to date, considering public and private funding. And that seems to me like a fairly major investment in a technology that still is not ready for commercialization.

How much longer is it going to take?

You may have answered this question before I entered the room, but I'm curious to know how many more years of funding will be required before we're ready to take this to market.

Mr. PARKER. I'm not in a position to answer that. I don't come from the manufacturing sector at all. Even as a person, you know, and the Fuel Cell Association itself is not privy to what goes on as it relates to proprietary information of manufacturers.

The answer is really not unique, a unique answer. It's a function of what technology you're discussing. And there are at least three basic technologies that we address. The one that's closest is phosacid.

The Department of Energy's position is that it doesn't need any more money to bring that to commercialization, leave it with the manufacturers.

Our position is it's almost there, but it's not quite where manufacturers can pick it up.

Mr. BOUCHER. So you need some demonstration funding for that.

Mr. PARKER. You need some. And what's called a public offering by one of the manufacturers, I'll give you street hearsay on this because, again, you would have to talk to them to get the actual answer.

But, that's a limited public offering. It's on an invited basis. And it's at the 200 kilowatt only level. So it doesn't address larger units. The technology that they have incorporated in this limited offering, its funding will be cut off in the last year of its testing for the stack itself, which has been funded for years by DOE.

So you have one technology that's very close that's being put into a bust demonstration program, another technology that's right after the year 2000.

Mr. BOUCHER. Mr. Schora.

Mr. SCHORA. Yes, Mr. Chairman.

In relation to when we see penetration into the market, and quite frankly, initial penetration from a common sense standpoint is to introduce it as a natural gas fuel system initially. And we're looking for demonstration at that level of 500 kilowatts, say, to two megawatts, in the time frame of about 1994–95.

Now, molten carbonate fuel cells have been under development obviously for a long time, as indicated by the funds expended. IGT has been working on it for close to 25 years.

However, there were some very fundamental problems to be resolved. I think these have been resolved. This is one reason why we formed this corporation and it received private funding, to see it now into commercial size scale-up and commercial size production.

So I think we're getting close.

Mr. BOUCHER. Let me finish this round of questioning with what we in the courtroom would call a friendly leading question.

In the event that we do not continue the investment which now totals almost $900 million in this fuel cell research, do we run the risk that, ultimately, the United States will have to buy this technology from a foreign source?

Are there foreign developers who are roughly where we are in this process? Behind us? Ahead of us?

What do we face on the international front?

Mr. SCHORA. From my knowledge of what's going on, there's significant monies being spent today in Europe and very significant monies being spent today in Japan. I think the Japanese see this as a potential new device much like the VHS players and everything, where if they invest enough, they can come away with a worldwide market.

I think we have to attempt to prevent that from occurring in that we were basically the pioneers of the program.

Mr. BOUCHER. Where do we stand in relation to the Europeans and Japanese?

Mr. SCHORA. Well, I think, as was mentioned five years ago, they were behind us. Today, in some aspects of the technology, they're significantly ahead of us.

Japan I think is projecting from the government side an expenditure in the molten carbonate area over the next five years of over $200 million.

And with industry, knowing how industry operates in Japan, I would suspect there will be an equivalent or more money spent by the private sector in Japan.

So it's very formidable and if we don't achieve continued support by the government, I think we'll be importing these stacks in the future from overseas.

Mr. BOUCHER. So what you're suggesting is that, in order to reduce the trade deficit, we need to increase the budget deficit?

Mr. SCHORA. I think good vigor is the way to go on this, yes.

Mr. BOUCHER. Thank you.

Mr. Smith?

Mr. SMITH. I don't have any questions.

Mr. BOUCHER. Gentlemen, we thank you very much. You've been very informative. It's good to have you with us.

We have a final panel, Mr. Edward Reid, from Columbia Gas System Service Corporation, representing the American Gas Association; Dr. Vincent Coates of the MHD Forum; and Mr. Len Peters from the University of Kentucky.

Without objection, your statements will be made a part of the record. We would appreciate your summarizing your testimony. We will withhold questions from the panel until all of the witnesses have presented their opening statements.

And, Mr. Reid, if you're prepared, we'll begin with you.

PANEL 2: FUEL CELLS

STATEMENT OF EDWARD A. REID, JR., COLUMBIA GAS SYSTEM SERVICE CORP., ON BEHALF OF THE AMERICAN GAS ASSOCIATION, ARLINGTON, VA

Mr. REID. Mr. Chairman and members of the Subcommittee, I'm Ed Reid, Manager of Utilization Research for the Columbia Gas Service Corporation. I am here appearing on behalf of the American Gas Association.

The United States needs an adequately-funded DOE research program not only to meet future energy needs, but also to remain competitive in today's world economy.

Gas-related research may be the most important component of DOE's research program. Natural gas is an abundant, economic, efficient, flexible, environmentally sound fuel. In addition, natural gas has been identified as a part of the solution to many of our environmental problems.

To ensure that natural gas can contribute to the solution over the long-term, R&D is needed to increase recoverable gas supplies and improve end use technologies.

The gas industry recommends $125.8 million for all DOE gas-related research and development. This compares to $114.35 million last year. The three major increases in our request are related to energy efficiency in the areas of natural gas—high efficiency heat engines and gas-powered fuel cells.

These are especially important as a means to reduce air pollution. Specifically, AGA recommends $73.4 million for fossil energy R&D, with $15 million for unconventional natural gas recovery; $39 million for conservation R&D, with $9.5 million for a natural gas vehicle R&D program; and $13.4 million for renewable energy R&D.

We commend DOE for increasing its FY-1990 gas-related R&D budget request by 40 percent over the 1989 request. However, it is still a long way from the Congressional appropriation of about $100 million for total gas-related R&D last year.

We are pleased that your Subcommittee had the foresight to enhance DOE's request for FY-89. The gas industry recommends funding of $15 million for the critically-important unconventional gas recovery program in FY-1990. In addition to this specific program, we also recommend strong support for a geoscience research effort aimed at increasing the understanding of gas and oil-related exploration and recovery processes and improving such technologies.

While Congress has recognized the need for a stronger geoscience program, actual appropriations for geosciences research have not nearly been sufficient.

We commend this subcommittee and the full Science, Space and Technology Committee, which took a very important step last year when it authorized $20 million solely for a gas and oil-related geosciences program above and beyond its authorization for the traditional unconventional gas recovery and petroleum R&D program.

We encourage the Subcommittee to take similar action again this year. We are pleased that last year the Department of Energy focused greater attention on natural gas by releasing a study bulletin entitled, quote, "An Assessment of the Natural Gas Resource Base in the United States."

We hope that the next step would be DOE's support of adequate gas supply related research to ensure the recovery of a larger percentage of total gas resources.

Federal funding is necessary to the long-term, high-risk development of the technology base which is essential to further the nation's goals of energy security and environmental quality.

We also recommend $9.5 million for natural gas powered vehicle program. This includes providing the full funding necessary to implement the natural gas vehicle development and demonstration programs authorized in the alternative Motor Fuels Act of 1988.

In addition to this effort, however, more fundamental research on natural gas combustion, carburation, manifolding, gaseous fuel injection, power optimization and emissions control is needed to optimize the performance of natural gas in motor vehicles.

Broad development of vehicles fueled by compressed natural gas would serve the national interest by improving air quality, since NGVs produce a fraction of the harmful emissions of gasoline in diesel-powered vehicles.

In the renewable energy area, we recommend $8.4 million for geopressured methane. This is a very long-term, very high-risk research effort. Significant amounts of methane can be recovered from these reservoirs if technological breakthroughs can be achieved in this program.

Estimates of this resource range up to 1,200 trillion cubic feet.

Another area where supplemental methane supplies can be found is converting biomass and waste into useful energy. Therefore, we recommend $5 million for biofuels initiative.

In conclusion, the natural gas industry recognizes that the continuing budget deficit places severe constraints on federal energy research dollars. Our total recommendation this year is higher than previous years because of the increasing urgency to promote energy conservation through more efficient end-use technologies.

And with the additional focus of the Administration, Congress and the public turning towards clean air problems in a general consensus that natural gas has a larger role to play in solving these problems, increased federal funding for research and development is necessary to implement the national goals.

However, our recommendation is still conservative, requesting funding for only those technologies that are essential and prudent with the orderly development of new domestic gas supply and utilization technology.

If Congress adopts our research recommendations, the nation will over the long-term improve its energy supply security and energy efficiency.

Thank you very much.

[The prepared statement of Mr. Reid follows:]

TESTIMONY OF EDWARD A. REID, JR.
MANAGER, UTILIZATION RESEARCH
COLUMBIA GAS SYSTEM SERVICE CORPORATION
ON BEHALF OF
THE AMERICAN GAS ASSOCIATION
BEFORE THE SUBCOMMITTEE ON ENERGY
RESEARCH AND DEVELOPMENT
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES
ON THE FY 1990 DEPARTMENT OF ENERGY
RESEARCH AND DEVELOPMENT BUDGET
FEBRUARY 22, 1989

Mr. Chairman and Members of the Subcommittee, I am Ed Reid, Manager, Utilization Research for Columbia Gas System Service Corporation. I am appearing on behalf of the American Gas Association (A.G.A.). The American Gas Association is a national trade association comprised of some 250 natural gas distribution and transmission companies serving over 166 million natural gas consumers throughout the United States. We appreciate this opportunity to present our views on natural gas-related research and development (R&D) conducted or sponsored by the Department of Energy (DOE).

The natural gas industry recommends an authorization of $125.80 million for all DOE gas-related R&D in Fiscal Year (FY) 1990. This total is broken down as follows: $73.40 million for fossil energy R&D; $39.0 million for conservation R&D, which includes $9.5 million for a natural gas vehicle R&D program; and $13.4 million for renewable energy R&D.

THE IMPORTANCE OF GAS-RELATED RESEARCH

The United States needs an adequately funded DOE research program not only to meet future energy needs, but also to remain competitive in today's world economy. Gas-related research may be the most important component of DOE's research program.

Natural gas energy has an important future role because its attributes favor its use in a myriad of applications. First, gas is the cleanest of all fossil fuels. Gas can be used for pollution control by itself and to reduce sulfur and nitrogen oxide emissions of other fossil fuels. Gas can also be used as a vehicular fuel. No other single fossil fuel can be used in as many applications as natural gas without major negative environmental consequences. Indeed, the air pollution problems resulting from the combustion of other fossil fuels has caused many in Congress and the Administration to call for solutions to the ozone nonattainment, acid deposition, and potential global warming problems facing the nation today.

Second, natural gas can be delivered quickly, efficiently and without major environmental impact, through the existing million-mile transmission and distribution system.

Third, natural gas can be converted into usable energy more efficiently and inexpensively than other fossil fuels. The efficiency of current gas utilization technologies ranges from 98 percent for residential heating to 70 percent for industrial cogeneration and 50 percent for combined cycle turbine systems for electric generation.

DOE's role in gas research serves two very important purposes. First, DOE's support of gas supply-related research will ensure the recovery of a larger percentage of the total gas resource base, which is several thousand times larger than the presently recoverable gas resource base. The amount of gas that may be recovered from the total gas resource base is directly contingent upon our ability to develop new tools and techniques to recover this gas at commercially viable prices.

In May 1988, the Department of Energy released a study entitled, "An Assessment of the Natural Gas Resource Base of the United States." This study concluded that, in the lower 48-states, there are 1,059 trillion cubic feet (Tcf) of gas that can be tapped with existing technology. At the 1987 level of nationwide gas consumption, this amount is equivalent to a 62-year supply. While the number is encouraging, and is indeed conservative, if natural gas is to be the cornerstone of the Administration's energy policy, technological breakthroughs will be necessary to increase long-term gas supplies dramatically. Federal funding is necessary to development of a long-term, high-risk technology base essential to achieve these breakthroughs.

We are pleased that Congress has recognized the importance of gas-related research. Over the past few years, Congress has consistently authorized and appropriated much more funding for natural gas R&D than the Administration has recommended, especially in the areas of unconventional gas recovery, geopressured resources, gas-related fuel cells and gas-related conservation programs.

While Congress has recognized the need for a stronger geoscience program, the funding has not nearly been sufficient. DOE has made organizational and structural changes recommended by the February 1987 ERAB report to DOE, "Geoscience Research for Energy Security." Unfortunately, organizational changes alone are not enough. The most important recommendation by ERAB was a call for significantly higher funding levels for gas and oil-related geoscience research. To date, such dramatic funding increases in gas-supply related research programs have not materialized. Therefore, to truly implement a geoscience program as envisioned by ERAB, we recommend that Congress provide a strong funding base for cross-cutting geosciences research which will benefit both gas and oil exploration and production.

The second purpose of DOE's involvement in gas research is to provide funding for technologies that radically change the manner in which we use natural gas. Significant improvements can be made in the area of energy efficiency. Such improvements are at the cornerstone of many bills introduced in both the 100th and 101st Congresses. For example, further research on electrochemical processes and thermodynamics could improve the process for transforming gas into usable energy, with greater efficiency and no adverse environmental impact. DOE can and must play a central role in gas technology development, in order for the U.S. to reduce its reliance on foreign oil, improve its energy efficiency to enable industry to compete in the global marketplace, and reduce pollution.

To facilitate DOE's role in natural gas energy research, A.G.A. recommends that there should be created within the Department a new Assistant Secretary position, the Assistant Secretary for Natural Gas. This person would coordinate vital departmental natural gas initiatives on both the supply and demand side. Many of the national goals that President Bush seeks can be enhanced by the creation of this position. This new Assistant Secretary for Natural Gas should be empowered to establish a natural gas policy for the nation and to coordinate it with all federal agencies. The new Assistant Secretary could direct all agencies, including independent regulatory agencies such as FERC, to consult with the Secretary/Assistant Secretary before taking any action that could affect the nation's natural gas policy.

SPECIFIC FUNDING RECOMMENDATIONS

FOSSIL ENERGY R&D: $73.40 Million

(1) Unconventional Natural Gas ($15 Million)

Large amounts of natural gas have been identified in tight geological formations such as Devonian shales and tight sands. Devonian shales and tight sands are estimated to contain more than 1,800 Tcf and 900 Tcf of natural gas, respectively. Tight formations gas is produced using unconventional recovery techniques. A.G.A. estimates that favorable economic conditions and substantial investment in advanced recovery techniques could result in annual "incremental" production of up to 4.0 Tcf of gas by the year 2000, while the current rate of technology would produce approximately 1.0 Tcf by that year.

In order to optimize the amount of natural gas recovered from our abundant resource base, basic geoscience research must be expanded. This research should be aimed at increasing our knowledge of the geological/geochemical/geophysical characteristics and parameters of both conventional and unconventional formations. This cross-cutting, reservoir characterization-type research is essential to both exploration and production in new formations, which are characterized by subtle traps, and to the application of secondary recovery techniques in existing fields.

Moreover, because of the potentially enormous size of what we call advanced unconventional natural gas resources (*e.g.*, gas hydrates and deep source gas), extensive research is necessary just to verify how much may be technologically and economically recoverable. For instance, early R&D efforts in the area of gas hydrates and deep source gas will help define the scope of the resource.

To enhance the development of technology necessary to recover the natural gas from unconventional gas formations, more research must also be conducted to develop advanced stimulation techniques to fracture tight rock formations that restrict gas flow. Current fracturing techniques induce only shallow fractures of a few hundred feet. Field testing must be conducted to refine techniques for inducing deep fractures of several thousand feet and to control the direction of the fracture better for optimal production results.

Also, research information must be collected from field testing to estabish a technological database for stimulation modeling, economic modeling and other analytical purposes. In addition, advanced drilling techniques (directional and horizontal) must be refined and improved to increase production rates and reduce drilling costs. We are recommending funding of $15 million in the unconventional natural gas recovery program to continue DOE's secondary gas recovery program and ongoing research activities in western tight sands, Devonian shales, and other complex formations and to support expanded geoscience-type research.

(2) Surface Coal Gasification ($3.4 Million)

Surface coal gasification is an important technology that can augment future natural gas supplies. A.G.A. projects that, by the year 2000, surface coal gasification has the potential to contribute approximately 100 billion cubic feet (Bcf) of additional gas supplies. However, with vigorous R&D support, surface coal gasification could contribute up to 200 Bcf to our supplies.

Contemporary technologies allow significant production of gas from coal; however, substantial research into the gasification process is necessary for synthesized gas from coal to play a role in meeting this nation's future energy needs. Gasification techniques must be developed to accommodate high-sulfur Eastern coals and combustion-inhibiting coal "fines." Research must be conducted to develop techniques for gasifying these "fines," for disposition of liquid byproducts, and for consolidating "fines" and tars for utilization.

Scientific and engineering feasibility studies of advanced generation gasification processes must also be conducted to develop a technological database for such processes. In addition, research must be conducted to identify the proper treatment and disposal techniques for gasification waste byproducts.

(3) Fuel Cells ($36.5 Million)

Natural gas-powered fuel cells, in a highly efficient electrochemical process, convert the energy content of gas directly into electricity and byproduct heat. The electrical conversion efficiency of gas-powered fuel cells is approximately 15-20 percent greater than the conversion efficiency of traditional electrical generation. Combining fuel cells with certain cogeneration applications could achieve combined electrical and thermal conversion efficiencies of 80 percent, compared to conversion efficiencies of 30-35 percent by conventional central station electric plants. Fuel cells are also environmentally benign, emitting virtually no pollutants. As work on the phosphoric acid fuel cell reaches its conclusion, the gas industry's focus is directed toward the development of advanced fuel cells, which will operate at higher temperatures making them conducive to industrial applications and achieve even higher efficiencies.

Research must be conducted to develop second-generation molten carbonate fuel cells capable of processing gases containing various impurities, as well as to develop other advanced, direct conversion concepts, such as solid oxide fuel cells. Because of its importance, we recommend a total of $36.5 million for fuel cells of which $25 million should be used to support development of molten carbonate fuel cells, $9.5 million for continued development of advanced concepts such as solid oxide fuel cell technologies, and $2 million for an advanced technology base for phosphoric acid fuel cells. The second and third generation fuel cell concepts are still years away from commercial use and, therefore, are critically dependent upon continuity of federal R&D support to supplement industry efforts.

(4) Heat Engines ($10.0 Million)

Because of their contribution to the environment and energy conservation, we recommend a research and development program in DOE's Heat Engine Program for the development of high efficiency natural gas-powered turbines for electric generation. Such a program should include advanced combined cycle gas turbines, steam-injected gas turbines (STIG) and intercooled steam-injected gas turbines (ISTIG). The ISTIGs, in particular, are fifty percent more efficient than conventional powerplants, and cost half as much as new coal or nuclear plants and can make great contributions to the nation's clean air problems. Two million dollars of this is for research on combustion systems emissions control.

(5) Underground Coal Gasification ($2.5 Million)

Underground coal gasification is the process whereby coal is burned underground, in formation, generating a low-Btu or medium-Btu gas. The coal is gasified by drilling boreholes into the coal seam, igniting the coal and injecting air, steam or oxygen into the reaction zone. The hot gas is forced through the seam to an exit borehole where it is carried to the surface and processed to remove impurities. The gas can then be used directly as an energy source or can be upgraded to pipeline quality through catalytic methanation and subsequent gas processing.

Underground coal gasification could substantially increase the nation's coal resource base, 93 percent of which presently cannot be recovered economically using conventional mining techniques. Moreover, underground coal gasification offers potential environmental, economic and safety advantages over conventional mining.

Extensive field testing is necessary to understand the technological basis for linking the vertical wells through the coal seam and controlling the movement of the reaction zone. Extensive environmental monitoring is also required to analyze and control the potential contamination of surface water and local aquifers, and to control surface subsidence.

To date, DOE sponsored field tests of the controlled-retracting-injection-point (CRIP) technology have been successful and we must now analyze the results of these tests, determine if this technology is applicable to other coal seams, and complete environmental work at the test site. This technology needs to be demonstrated now on Eastern bituminous coals.

(6) Advanced Research & Technology Development ($6 Million)

The Advanced Research and Technology Development program generally supports basic research in combustion chemistry, engineering concepts and materials and components that provide a technology base for ongoing fossil energy projects and for advanced process development, such as coal gasification and fuel cell systems. Current research needs include: improving the understanding of the interactions of coal gasification processes in a fluidized-bed environment; improving the understanding of the interaction of gasification catalysts with carbon/steam and carbon/hydrogen reactions; developing advanced processes for low-cost synthesized gas; developing lower-cost acid-gas cleanup processes; and continuing efforts to assess advanced cleanup technology for alkali metals, particulates and tars.

CONSERVATION: $39 Million

(1) Natural Gas-Powered Heat Pumps ($10 Million)

By extracting heat from the outside air and transferring it to the indoor space, gas heat pumps can actually supply more thermal energy than is contained in the fuel that they use. The gas heat pump's cooling effect is accomplished by reversing this process. The gas heat pump provides heating and cooling in a single unit using less energy than a conventional or high efficiency furnace uses for heating alone. Current performance estimates suggest that in heating, the gas heat pump could save one-half of the gas used in a conventional furnace and one-quarter of the gas used in a high efficiency furnace.

More research is necessary to develop highly-efficient, reliable and cost-effective gas heat pumps for residential and commercial applications. In order to improve durability, maintenance and endurance, such research must include the evaluation of promising technical approaches, fundamental research in basic heat pump concepts, processes, phenomena and materials, and research on generic component development. These activities must be integrated into overall gas heat pump system development and analysis. Presently, the most promising gas heat pump concepts are the dual cycle absorption concept, absorption technology using fluids in novel cycles, and engine driven concepts using improved and emerging internal combustion technology.

(2) Natural Gas Vehicles (NGVs) ($9.5 Million)

Development and utilization of vehicles powered by compressed natural gas would serve the national interest by improving air quality, since the emissions from natural gas vehicles (NGVs) contain only a fraction of the nonmethane hydrocarbons, carbon monoxide, and nitrogen oxide produced by gasoline-powered vehicles. Furthermore, unlike gasoline-powered vehicles, NGVs emit almost no sulfur oxides or particulate matter. Fleet use of NGVs in congested cities would provide a significant benefit to those areas where air quality improvement is most critical. In addition, substantial potential exists for emissions reductions from diesel engines through the use of natural gas/diesel fuel mixtures in those engines.

Conversion to partial or dedicated natural gas/heavy duty diesel engines holds the promise of a low-emissions engine, but further R&D is required to address the well recognized technical difficulties. Moreover, the technology-forcing EPA particulate emissions standards effective in 1991, make development of advanced, dedicated natural gas-powered heavy duty engines imperative.

Congress recognized the need for developing natural gas-powered heavy duty trucks and buses when it passed the Alternative Motor Fuels Act of 1988 which authorized $6 million for the development and demonstration of alternative fueled trucks and buses. In addition to funding this activity, however, additional funding is needed to conduct R&D on natural gas vehicles in general.

Fundamental research is necessary to acquire a thorough understanding of the intricacies of gaseous fuel injection, carburetion, manifolding, combustion, power optimization and emissions control so that natural gas can become broadly accepted as a transportation fuel. Further research into novel gas compression concepts is necessary to advance the development of compressor technology. Research must also be conducted on advanced storage systems (*e.g.*, sorbent materials) to increase the understanding of gas storage technology, particularly the fundamental principles of natural gas adsorption, absorption, clathration and catalysis.

(3) Other Projects ($19.5 Million)

Other research projects that are included in our conservation recommendaton of $39 million are: (a) $3.0 million for DOE research on indoor air quality; (b) $8.5 million for tribology, ceramics, and other materials-type research in the energy conservation utilization technology program (ECUT); and (c) $8.0 million for research on desiccant technology that is used in gas cooling.

RENEWABLE ENERGY: $13.4 Million

(1) Geopressured Methane ($8.4 Million)

Geopressured methane is found in either a free state or dissolved in water and trapped in sedimentary rock at higher-than-normal pressures. One of the largest geopressured areas underlies a portion of the Texas and Louisiana Gulf Coast. Estimates of the total resource in-place range up to 100,000 Tcf; however, estimates of the amounts of gas that might ultimately be recovered, given current recovery techniques, range between 25 and 1,200 Tcf. If technological breakthroughs can be achieved, geopressured methane could become a virtually inexhaustible source of domestic energy.

Research conducted by DOE in geopressured/geothermal zones is focused on producing both gas and electricity from low-grade heat in the reservoir brine. DOE should redirect its research efforts and concentrate more on recovering the vast amount of dissolved methane found in geopressured zones. In addition to DOE's current geopressured program, DOE should develop new approaches that utilize traditional engineering principles to maximize gas production and minimize brine production.

(2) Biofuels ($5 Million)

Since the supply of organic and waste materials is virtually unlimited, supplemental methane supplies from biomass and waste conversion can add significantly to the total future gas supply picture. Finding sites for disposal of waste is an increasing problem in communities across the nation. The New York garbage barge this past year is a graphic example of the enormity of the problem. Therefore, developing energy from biomass would promote the environmental benefit of productive use of currently "useless" materials. However, the quality of the gas produced and a suitable processing technique are important concerns that inhibit the widespread use of these potential gas resources.

The gas industry fully supports the gas-related biofuels R&D being carried out at the Solar Energy Research Institute (SERI) and recommends strong federal support for continuation of these important activities. Advances have been made in both the thermochemical and biochemical conversion processes, but more extensive studies and technology advancements are necessary to fulfill biomass' contribution as a useable source of energy.

Of particular interest to the gas industry is SERI's work in the biotechnology process of anaerobic digestion of municipal solid waste that includes genetic and other improvement of biological organisms and development of innovative reactor design concepts.

Another significant area of research at SERI includes methods to remove carbon dioxide from the air or from combustion plant stacks. $5 million is needed to perform these two gas-related initiatives in FY 1990. We also urge Congress to provide a strong, stable funding level for all biofuels research work at SERI. This research progam has experienced drastic funding cuts in recent years.

CONCLUSION

The natural gas industry recognizes that the continuing budget deficit places severe constraints on federal energy research dollars. Our total recommendation this year of $125.80 million is higher than previous years because of the increasing urgency to promote end-use technologies and conservation. With the focus of the Administration, Congress and the public at large turning towards clean air problems, and a general consensus that natural gas has a major role to play in solving this problem, increased federal funding for research and development to increase natural gas supplies and utilize this gas more efficiently is necessary to implement the national goals. However, our recommendation is still conservative, requesting funding for only those technologies that are essential and prudent for the orderly development of new, domestic gas supply and utilization technologies. If Congress adopts our research recommendations, the nation will, over the long term, improve its energy supply security and energy efficiency.

Mr. Boucher. Thank you, Mr. Reid.

Dr. Coates, we'll be happy to hear from you.

STATEMENT OF VINCENT J. COATES, JR. MHD FORUM, ACCOMPANIED BY DR. BILL OWENS OF GILBERT COMMONWEALTH, WASHINGTON, DC

Mr. Coates. Thank you, Mr. Chairman. I appreciate the opportunity to be here today. I have a statement from Gary D. Smith at the University of Tennessee Space Institute on behalf of MHD, which I'd appreciate—

Mr. Boucher. Without objection, that will be made a part of the record.

[The statement from Mr. Smith follows:]

STATEMENT OF GARY D. SMITH
SPECIAL ASSISTANT TO THE DEAN
THE UNIVERSITY OF TENNESSEE SPACE INSTITUTE
TULLAHOMA, TENNESSEE 37388

SUBMITTED TO

THE SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U. S. HOUSE OF REPRESENTATIVES
WASHINGTON, D. C. 20515
FEBRUARY 22, 1989

Madam Chairwoman and Members of the Subcommittee, I appreciate the opportunity to describe developments in magnetohydrodynamics (MHD) research and development during the past year. Significant international interest in and commitment to MHD technology continues to develop and is reflected in accelerating international MHD activity. At the same time, substantial progress continues to be made in all phases of the United States MHD program. A summary of the significant advances in the U. S. MHD program is contained in the testimony given today by the MHD Industrial Forum. This progress is possible only because of the continuing support of the United States Congress for this vital technology, a technology which promises to play a prominent role in the near future in international trade, energy independence, and even national defense. I sincerely appreciate the support of this Subcommittee in the past and solicit your continued support for this program in the future.

Magnetohydrodynamics is the 'high tech' of coal technology. MHD is the energy conversion technology which holds the potential for achieving the highest plant efficiencies while exceeding all standards for environmental intrusion. Coal-fired MHD plants have experimentally verified levels of sulfur dioxide (SO_2), oxides of nitrogen (NO_x), and particulate emissions well below the New Source Performance Standards of 1979 without using expensive exhaust gas cleanup systems required on conventional power plants. Data obtained at the U. S. Department of Energy's Coal Fired Flow Facility, located on the campus of the University of Tennessee Space Institute near Tullahoma, Tennessee, have verified the environmental performance of coal-fired MHD technology.

In addition to the inherent reduction of suspected 'acid rain' precursors, the MHD technology has been ranked by the U. S. Department of Energy as having the highest potential to reduce carbon dioxide emissions (the principal contributor to the so-called greenhouse effect) from a coal-fired electric power generating system. According to a report published in The Energy Daily(1), DOE estimates a 34 percent reduction in CO_2 emissions from a coal-fired MHD combined cycle compared to a conventional pulverized coal-fired power plant. The report further states "A natural gas-fired MHD system, with an efficiency of approximately 50 percent, would reduce CO_2 emissions by a projected 57 percent ..." In both cases, the reductions in CO_2 emissions are inherent in the MHD process and require no additional exhaust cleanup equipment.

During the past five months, the University of Tennessee Space Institute has entered into separate cooperative agreements with an Italian consortium and with the People's Republic of China to develop the MHD technology for commercial electrical power plant applications. Both programs are targeted on retrofitting existing fossil fueled power plants with MHD systems to improve the performance, reduce the pollutant emissions, and extend the life cycle of the plants.

The Italian consortium, which includes the government and three industrial firms, has the stated objective to market MHD retrofits throughout the world during the 1990's. They have the potential to become a major competitor to American industry in the power plant market, both internationally and domestically.

Recently, a prominent Chinese scientist reported(2) "...a new National Coal-Fired MHD program has been approved by the State Science and Technology Commission of People's Republic of China. This program begins in 1988 ..." His report concluded that in China, "... MHD has been cited as the key high technology science for coal utilization. Under the guidance of this national program an acceleration of MHD research in China has begun." He concluded by stating that MHD technology will be "... an important method of technological reconstruction and improvement of electrical power plants in China."

But the international competition is not limited to Italy and China. The New York Times reported(3) "An international race is on to commercialize a highly efficient form [MHD] of electricity generation ... The Soviet Union has a head start.... But Israel may be the first across the finish line with a small commercial version." Popular Science magazine reported(4) "The Israelis seem about to win the race to produce commercial electric power from a potentially highly efficient process called ... MHD." The report said "Israeli researchers ... now have one prototype operating, and expect to have a larger commercial unit working in two years."

MHD power generation continues to be studied for a wide range of applications in addition to stationary electric power plants. The Soviet Union has previously reported(5) utilizing a pulsed MHD generator for geophysical research. It was reported(6) in 1985 that the Soviets used an MHD generator to power a laser. Currently studies are in progress in the U.S. to assess the potential of an MHD generator as a space-based electric power source for military applications(7). The U. S. Air Force is studying the feasibility of designing large MHD-driven ground test facilities for hypersonic flight testing. Inside the Pentagon recently reported(8) "The Defense Advanced Research Projects Agency (DARPA), as part of its advanced submarine technology program, is exploring a propulsion technology called magnetohydrodynamics or 'MHD' that Pentagon officials say could lead to much faster and quieter submarines." That same report noted that "the Japanese are moving quickly on the idea and the Soviets reportedly are experimenting in the same arena." Just last month, New Scientist reported(9) on Soviet application of MHD technology to power submarines and stated "But the principle is sound - MHD generators are believed to power the creep motor of the Soviet Victor III class submarines ..." Clearly, MHD is a technology that is attracting growing international attention with potential applications in energy, geophysics, space weapons, hypersonics, and ocean propulsion.

The MHD community in the U. S. is gravely concerned by the rapid erosion of our technological leadership and international competitiveness. Many experts feel that our unacceptably high international trade deficit has been exacerbated by our declining position of technological competitiveness. We must remain competitive and lead the development of MHD technology if we are to maintain a position in world trade markets. American competitiveness must be regained by increasing our productivity through the application of advanced technology. But to do this requires the vision by both government and business leaders to invest in the future. Development of new technology and training of qualified specialists requires investment today.

The United States remains the world leader in coal-fired MHD technology today, although our leadership is being seriously threatened on many fronts. We simply cannot afford to sacrifice our technological edge in MHD as we have in so many other technological areas. Any further delays in the implementation of the MHD technology will play into the hands of our worldwide competitors. I fully understand the budget constraints facing this Congress and our great Nation, and we are all willing to do our share. There are many programs that this Congress will be able to afford, and many programs that cannot be afforded. **MHD is a program that we CANNOT AFFORD NOT TO COMPLETE.**

Thank you very much for providing me the opportunity to update you on these important elements of the MHD technology. I strongly urge you to authorize full funding for the MHD program to support the goals and promise of this exciting technology.

CITATIONS

1. The Energy Daily, Vol. 16, No. 150, August 5, 1988.

2. Zixiang, Ju. "MHD National Program of China" 26th Symposium on Engineering Aspects of Magnetohydrodynamics, Nashville, Tennessee, June 20-22, 1988.

3. Wald, Matthew L., "A Race to Make an Old Power-Plant Idea Work", The New York Times, July 27, 1988, pg.35.

4. "MHD Race", Popular Science, September, 1988.

5. Freeman, Marsha, "MHD Pulsed Power for Geophysics and the SDI", Science and Technology, February 13, 1987.

6. Anderson, Jack, and Van Atta, Dale, "Soviets Take the Lead in Space Lasers", The Washington Post, September 6, 1985.

7. Carabetta, Ralph A., Chambers, Harold F., Staats, Gary E., and Elia, Gerard G., "An Overview of DOE and SDIO MHD Program Activities at PETC", AIAA 26th Aerospace Sciences Meeting, January 11-14, 1988, Reno, Nevada.

8. Inside The Pentagon, Vol. 4, No. 43, October 28, 1988.

9. Murphy, William Scanlan, "Dive! Dive! Dive!", New Scientist, January 7, 1989.

Mr. COATES. Also, I thank Nancy for promoting me to Doctor. I don't have a doctorate. That's probably the closest I'll ever get to having one.

If you can at your convenience, I put several sheets, and if you could just follow through those, we'll get through this on your schedule.

MHD power generation represents the largest, the most advanced technology in terms of faraday—you'll note the last little picture—MHD gas is extracted directly—electricity is extracted directly from the gas as it flows through the magnetic field, thereby eliminating the intermediate steps required by conventional turbine generators or the earlier piston generators.

What that means in terms of practicality is that when MHD is developed, we will have extended its technology.

And with respect to extending the technology, and it was addressed before the Congress earlier this month, President Bush cited four major needs of the country. And Senator Bentsen in his response agreed.

And these needs were:

One, the need for Clean Coal and the need to clean the environment.

The second need was to extend our technology lead.

And the third need was to improve our competitive, the international.

I'm going to suggest to you in the next few minutes that MHD will meet each of those needs.

On the second page, first by extending MHD technology, as you're all aware, in the 1990s, there's going to be a major need to replace aging electric power plants and at the same time to increase capacity.

MHD will do that as this picture shows because you can retrofit conventional power plants, turbine generators, it said, with an MHD generator, which means you can use existing technology. You don't have to go out and buy new property, and you don't have to do away with old plants.

Also in terms of extending technology and, indeed, in cleaning the air, you'll see the efficiency.

MHD will have a 60 percent efficiency compared to the other technologies which are shown there. That means that we will be able to gain 50 percent more energy out of a ton of coal and at the same time reduce the CO_2 output also by 50 percent.

Going on to the next page, we talk about cleaning, using coal cleanly and improving the environment. The evidence is there in front of you.

My good friend, Secretary Wampler, suggested that it would cost another $114 million to complete this development. I would suggest that just the environmental improvements that should be accrued from MHD would be well worth that investment.

Going on to the next page, the President and Senator Bentsen also talked about extending our technology in international competitiveness.

You'll note the commercial and military technology fallout that we've already achieved through MHD. Under the military portion, you'll see submarine propulsion. There is some evidence that the

Soviet Union already has submarines in its fleet which are using MHD propulsion.

Again, I would suggest to you that the investment which this nation is making in MHD will be well returned in terms of the products which will become available and the technologies which will become available.

And I'd also remind the committee that computers, sensors, microchips, all of that technology came out of the government's investment in the Aerospace Technology areas both for the military and for NASA 30 years ago.

I'd suggest that in terms of talking of cost-sharing or any other investment that we need to keep in mind that technology can fall out. Not just from MHD but from all other technologies.

On the next page, I think your next page shows the budget figures. But the last page that you have shows MHD foreign program. If we don't do it, these other countries will. The Soviet Union already is designing and plans to build 500 megawatt MHD power plants. The Italians have an aggressive program because they've identified markets in southern Europe which could use MHD.

All these other countries you see here are doing the same thing.

And finally we come to the cost of this program. In order to complete this program, as the Secretary pointed out, it's going to cost another $114 million. And he says we can't afford it. I don't think it's a budget problem, I think it's a priority problem.

The problem has unrealistic priorities within the Department of Energy. You look at their budgets, something slightly less than 50 percent will be devoted to nuclear. Nuclear is an important technology. It needs to go forward. It's also important to clean it up, all the waste that we've recovered from nuclear power.

But is it reasonable to devote that much money when there are no plans on the part of any utility to put up another nuclear plant in the foreseeable future? When there's widespread public opposition?

And then you look at what they're going to suggest to you should be spent on fossil energy. Twenty-two percent of the fossil energy budget for coal: $107 million. A ridiculous 4.8 percent for oil, $24 million.

And a minuscule .8 percent or $4 million for GATT. Fossil energy, the three principal fuels which support this whole economy. And I suggest to you that you might like to take a look at that priority. And I'm not suggesting nuclear shouldn't be funded; it should. But certainly not to that extent.

Now, if you consider then MHD in that light, you'll note that we've provided you with two options. The plan which was put together by DOE and industry called for a program that would be completed in 1992 after which industry would cost-share 50 percent.

And by the way, with respect to cost-sharing, industry has met its obligations and this year is cost-sharing this program by 25 percent. Unfortunately, due to budgetary considerations last year, the budget was $37 million instead of $40.9 million. We wish to complete this program in 1992; we'll need $47 million this year.

If the budgetary constraints decision is to stretch this program out and delay many promises that we've discussed here today, then we can complete it in 1993, but it will cost an additional $20 million.

I'd suggest to you, that within the limits of this nation's fiscal problems, take a look at the priorities the Department has laid down before you. You'll be able to fund MHD and fuel cell and all the other fossil energy programs be carried forth and addressed.

Thank you.

[The prepared statement of Mr. Coates follows:]

Testimony of
Vincent J. Coates, Jr., Vice President
MHD Industrial Forum
900 Seventeenth Street, N.W. Suite 1100
Washington, D.C. 20006

to

The Subcommittee on Energy Research and Development
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, D.C. 20515

February 22, 1989

In his address to Congress earlier this month President Bush cited three national needs of interest to this subcommittee: the need for the "use of clean coal" to improve the environment, the need to "extend American leadership in technology" and the need to become more competitive in the world market. Senator Lloyd Bentsen, in his response that same evening, concurred with these needs.

The first portion of this statement discusses how Magnetohydrodynamic (MHD) electric power generation meets each of these bipartisan goals. Part two reviews the status of DOE's MHD development program.

MHD power generators extract energy directly from the combustion gases of fossil fuels -- coal, oil or gas -- without intermediary boilers, turbines or other rotating machinery essential to conventional power plants (Fig. 1). An MHD plant will operate at efficiencies as high as 60%, compared to the 35% efficiency achieved by the most advanced conventional power plants (Fig. 2).

MHD power generation was first demonstrated in the United States with technology derived from aerospace research. It represents the most important advance in the production of base load commercial power generation since the introduction of turbines in the early part of this century.

In terms of the President's and the Senator's call for environmental cleanup, MHD represents perhaps the most important advance in the control of power plant emissions.

MHD power plants will produce 87% less SOx, and 66% less NOx than EPA allows (Fig. 3). It will reduce power plant CO_2 emissions, thought to be the major culprit in the greenhouse effect, by 50%. This pollution control system is inherent in the MHD process. There is no need for expensive scrubbers that, by the way, produce sludge, a potential source of ground and water pollution.

MHD also will fulfill the mandate from President Bush and Senator Bentsen for improving the nation's competitive posture. Figure 4 lists the nations now conducting MHD development programs. The Soviet Union has the world's most aggressive MHD program. It is currently operating a small MHD pilot plant outside Moscow and is constructing a 500 Megawatt commercial power plant. The Italians are also undertaking an ambitious plan to develop retrofit units for a market they have identified in Southern Europe. Currently, U.S. MHD technology surpasses all other countries. If, however, our engineering development schedule continues to slip, it is inevitable that the Soviet Union and perhaps other nations will be marketing MHD power plants long before the United States.

The MHD development effort already has provided opportunities for the United States to extend its technological leadership. Beyond its future potential in power generation, MHD research and development is already contributing to commercial and military applications. In fact, as Figure 5 suggests, MHD may be unique among non-DOD research and development for the many and varied technologies it has spawned.

Indeed, MHD should be a reminder to those who question the appropriateness of an aggressive government-funded energy research and development effort that the nation's computer, microchip and related industries developed as a result of the government's investment in military and space technology.

In addition to considering the several ways in which an MHD research and development program responds to the needs expressed by President Bush and Senator Bentsen, an evaluation of the benefits of completing MHD development as rapidly as possible needs to take into account the MHD retrofit advantages.

America's utility plants are growing old. It is predicted that the United States faces an electric power shortfall beginning in the 1990's. MHD retrofit units offer an ideal solution. The electrical output and efficiency of existing plants can be upgraded by as much as 50% by connecting an MHD power unit to a conventional plant. MHD plants offer the added advantage of having no new land requirements, and fewer permitting requirements than completely new plants.

If the schedule set forth in the Redirected Proof of Concept Development Plan, prepared jointly by DOE and industry, is maintained MHD retrofitting can begin in the 1990's and the nation will begin to realize the goals set forth by the President and the Senator.

If, on the other hand, the program is delayed for budgetary reasons, MHD's many benefits will be postponed or lost and the development costs will increase. As Figure 6 shows, the nearly $4 million shortfall in FY 1989 will add one year and $20 million to the development program. Reduced annual budgets are particularly harmful during engineering development. Cost and schedules are amplified by delays in procuring hardware for systems needed in subsequent years. For example, the budgeted number for 1990 was $42.9 million. To meet the original FY 1992 completion target date will require $47 million in FY 1990, but would save $20 million in the overall.

As the subcommittee realizes, industry is cost sharing the development of MHD and is currently exploring various arrangements to obtain at least 50% of the retrofit investment which begins when the current program is completed.

I appreciate the fiscal constraints facing the Congress. But I do not believe that a substantial fossil energy budget adequate to fund MHD and other promising fossil energy projects are incompatible with the need for fiscal constraints. Fossil energy's budget problems are not fiscal. The problem is one of misguided DOE priorities.

Clearly, non-DOD nuclear energy research and development is important and should be funded. Is it good policy to allocate almost 50% of DOE's total budget to non-defense nuclear research and development when the general public opposes nuclear power and no nuclear power plants are planned for the 1990's?

The fossil energy portion of the budget raises serious policy questions. This nation's energy base depends upon coal, gas and oil. Indeed the dependency is so great we must rely upon foreign imports. Under the circumstances what logical rationale can there be for a fossil energy budget that provides only 22% for coal, 4.8% for oil and a ridiculous 0.8% for gas?

Perhaps when the new DOE management is confirmed, a more realistic balance may be developed. Meanwhile, I urge the committee to take the initiative to ensure that research and development programs for coal, gas and oil are funded in an amount that reflects their essential role in this nation's present and future economy.

I suggest that when the subcommittee examines DOE priorities, it will be found possible to authorize the dollars needed in FY 1990 to aggressively develop promising fossil energy programs including $47 million for MHD.

Program Status

A commercial MHD power plant will have two major subsystems. The first subsystem is the MHD topping cycle, and the second is the steam bottoming cycle. Both the topping and bottoming cycles produce electrical power that, when combined, represents the total output power from the plant. Gases exiting the topping cycle retain a great deal of heat at a relatively high temperature (typically 3600 F). Thus, the energy in the exchaust gas can be recovered in the bottoming cycle and used to generate steam for producing electric power to augment that from the MHD topping cycle.

As part of the National MHD Program, the U.S. Government operates two major test facilities -- the Component Development and Integration Facility (CDIF) and the Coal-Fired Flow Facility (CFFF). Data generated at these two sites will provide the information needed to predict the overall performance of full-scale, early commercial and mature commercial power plants and will be used to design the MHD unit to be retrofitted to a commercial power plant in the 1990's..

The CDIF, located in Butte, Montana, is designed for the testing of MHD components and power trains at the 50 MW(t) size. The purpose of the CDIF is to provide performance and durability tests of integrated MHD components, i.e., the MHD topping-cycle subsystem.

Currently, the CDIF is fully operational. Design power was achieved in August 1985 from the integrated topping-cycle configuration powered by a coal-fired combustor. In September 1986, the integrated topping-cycle subsystem was operated in a continuous test of approximately 8 1/2 hours, during which an average power of 1 MW was produced for 7 hours. The power produced was transmitted to the Montana Power Company's electric grid via an EPRI-supplied inverter.

Actual work on the MHD topping cycle POC tests at the CDIF was initiated in July 1984 when the first stage of a 50 MW(t), coal-fired combustor was delivered to the CDIF. Since that time, the coal combustor has been tested and integrated with the other components comprising the MHD topping-cycle subsystem.

The topping-cycle portion of the POC program consists of two sequential sets of activities. The first tests MHD topping-cycle components over a range of conditions stimulating those projected for early commercial plants. This portion of the POC test program is still in progress. The second set of POC activities will place emphasis on long-duration tests designed to culminate in a set of data required to predict and project MHD commercial-system reliability, availability, maintainability, and performance. A major task, which unfortunately was delayed by budgetary restraints, is to procure components for and to begin construction of a 1000 hour power train for this test.

The Coal Fired Flow Facility (CFFF), located on the campus of the University of Tennessee Space Institute (UTSI) is charged with providing data on the performance and durability of components that simulate an MHD bottoming cycle subsystem. These comonents provide for heat recovery, i.e., steam generation and air preheat, for the removal of spent seed/ash and slag, and for the cleaning and treatment of the effluent process flow.

During the 1988, UTSI successfully completed 593 hours of testing in the CFFF. A major and very significant milestone for boiler materials corrosion testing with Illinois #6 coal was reached in May 1988, when the first set of superheater tubes was removed for inspection and analysis after 500 hours of cumulative exposure. The corrosion testing on Illinois #6 coal will continue until a total of 2000 hours has been accumulated on the sample tubes. Metallographic analysis of the tubes is being performed jointly by Argonne National Laboratory, Babcock & Wilcox Company, and UTSI.

During the long duration testing in 1988, researchers were able to establish electrostatic precipitator operating limits that meet and exceed NSPS requirements for particulate emission levels in a coal-fired MHD system. Further testing under controlled potassium-to-sulfur ratios also established operating criteria for spent seed/ash removal in superheater tube sections and other bottoming cycle components. Extensive component performance and operating experience also were obtained on other bottoming cycle auxilliary components, such as sootblowers.

The extensive and unique data base being established at UTSI on bottoming cycle system and component performance characteristics will permit the design of commercial MHD plants to proceed with minimum risk. It is anticipated that the bottoming cycle proof-of-concept phase will be completed in 1992.

Test diagnostics for both the topping and bottoming systems is being provided by Mississippi State University.

In September 1987, a fifty-one month Integrated Topping Cycle contract was awarded to a team led by TRW, Inc., Redondo Beach, California. Prototypic hardware to be provided under this contract includes a 50 MW(t) coal-fired combustor, a 50 MW(t) MHD channel, a diffuser, and advanced power conditioning/inverter system, and appropriate spare parts. Systems engineering activities include power train/facility integration, test planning/review, and power train performance analyses.

TRW, in addition to providing overall integration of the work, will focus on all aspects of the POC effort associated with the coal-fired combustor. The development effort associated with the MHD channel and diffuser and the power-conditioning hardware will be conducted by the Avco Research Laboratory/Textron, and the Westinghouse Electric Corporation (respectively), as subcontractors to TRW.

The POC program being conducted at the CFFF includes durability tests on at least two coals for a total period of about 4000 hours (2000 hours per coal). The two coals of interest are Illinois No. 6 and Montana Rosebud. As a result of these tests, a data base will be completed on the heat and seed recovery portion of the cycle.

As presently configured, the CFFF is capable of processing (grinding and conveying) only eastern-type bituminous coal. Because of the higher moisture, volatiles, and oxygen contents of western subbituminous coals, the coal-handling facility is being modified to provide for increased drying capacity and an inerting system to prevent volatiles combustion or explosion.

As a result of an eighteen-month Integrated Bottoming Cycle contract awarded to Babcock and Wilcox, Alliance, Ohio, modification will be made to the coal drying and pulverization system at the CFFF to permit the processing of both bituminous eastern and subbituminous western coals. In addition, the contractor will design, fabricate, and install an automated system for collecting, weighing, and conveying spent-seed and ash materials, and complete the design of an intermediate-temperature air heater.

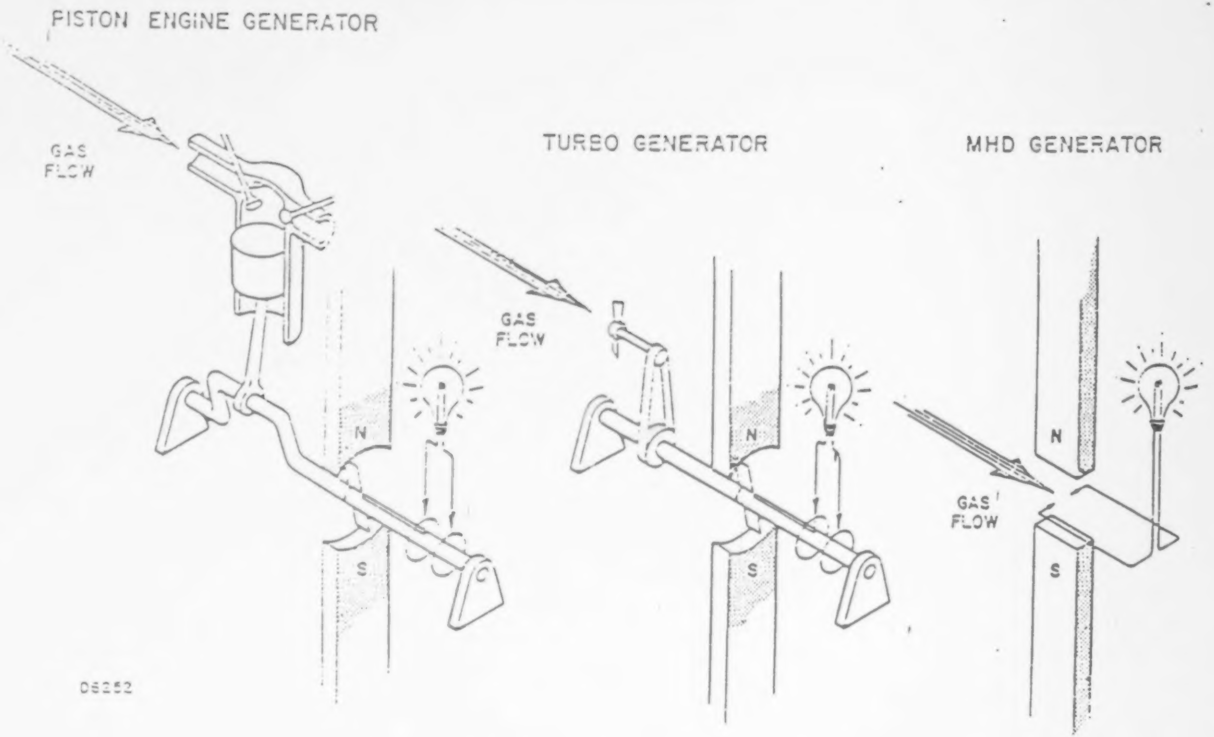
The technical and economic aspects of seed regeneration processes are being developed through three parallel contracts awarded to Babcock and Wilcox, Alliance, Ohio; the University of Tennessee Space Institute (UTSI), Tullahoma, Tennessee, and TRW, Inc., Redondo Beach, California. Phase I of these contracts, which has just been completed, encompassed bench-scale research and assessment of the technical and economic value of each specific regeneration process. Also provided as part of Phase I, were cost, schedule, and performance estimates for the POC plants; cost estimates for pilot plants sized to service a 300 MW(t) MHD power system; and three seed recovery and regeneration processes. DOE will select one process to proceed into Phase II. Phase II will include the design, construction, and operation of a seed regeneration plant to confirm process viability, and the refinement of the pilot-plant conceptual design.

It has long been recognized that retrofitting MHD power systems to existing plants may provide the most favorable route for commercializing MHD technology. The conceptual design of retrofit plants is an important element of the POC program which will provide information for the design of component parts for scale-up to commercial size. At the end of FY 1987, conceptual design contracts were awarded to the Westinghouse Electric Corporation, Pittsburgh, Pennsylvania, and the MHD Development Corporation (MDC), Butte, Montana, for study of the site-specific retrofitting of an MHD system to an existing fossil-fired utility plant. The Westinghouse study is based on Gulf Power's Scholz Plant located in Sneads, Florida, while the MDC study is based on Montana Power Company's Corette Plant in Billings, Montana.

Utility participation on each of these contracts is essential to the success of the overall effort. These studies will develop a conceptual design of the retrofit, together with schedules and cost estimates for the preliminary design, final design and construction of the retrofit. Upon completion of the conceptual design effort, a formal plan for financing the project will be presented by the host utility.

Figure 1

EVOLUTION OF THE MHD POWER CONCEPT


PISTON ENGINE GENERATOR

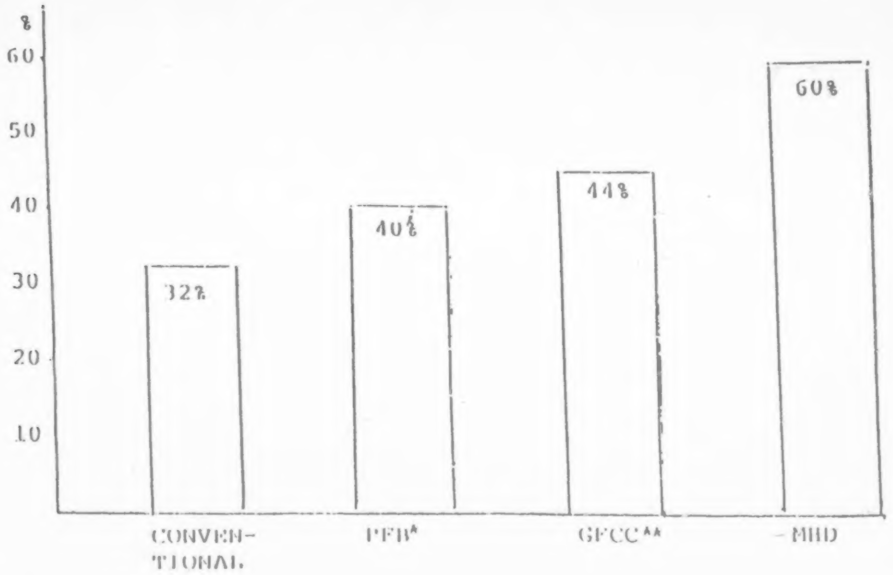
TURBO GENERATOR

MHD GENERATOR

An MHD generator requires no steam boiler, turbine or rotating machinery. In a conventional power plant, electricity is generated by rotating a solid copper conductor (armature) through a magnetic field. An MHD generator uses a high temperature conducting gas as its armature.

Figure 2

ADVANCED POWER SYSTEMS EFFICIENCY COMPARED TO CONVENTIONAL POWER PLANTS

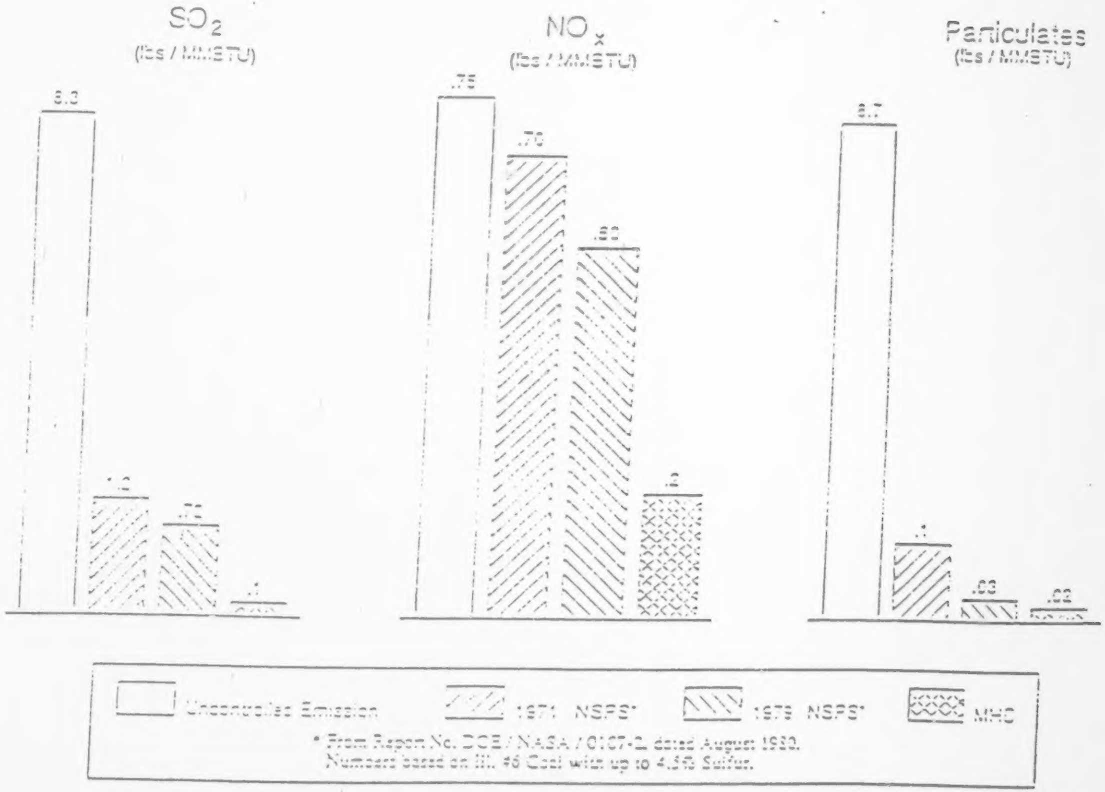


SOURCES:
DOE Advanced Power Train Studies by Westinghouse and General Electric
NASA Parametric Study of MHD Power Plants by General Electric and Avco Research Laboratory

*PFB: Pressurized Fluidiaed Bed
**GFCC: Integrated Gas Fired Combined Cycle Gas Turbine

Emission Levels from Coal - Fired MHD Power Plant

Figure 3



* From Report No. DOE / NASA / 0107-2, dated August 1980.
Numbers based on Ill. #6 Coal with up to 4.5% Sulfur.

CG-C808

Figure 4

MHD FOREIGN PROGRAMS

AUSTRALIA
CHINA
CZECHOSLOVAKIA
FINLAND
FRANCE
HUNGARY
INDIA
ISRAEL
ITALY
JAPAN
NETHERLANDS
POLAND
RUMANIA
USSR
YUGOSLAVIA

Figure 5

COMMERCIAL AND MILITARY TECHNOLOGY FALLOUT

Commercial

Pulse Power and Geophysical Applications

Ceramic Development

Utilization of slagging combustors as waste incinerators

Coal Beneficiation

DC to AC Invertor Technology

Dry Materials Transport

Materials Research

Load Management and Power Control

High Velocity Wind Tunnels

Coal Gasifiers

Glass Manufacturing

Iron Ore Reduction

Stabilized Super Conducting Materials

Military

SDIO Power Sources

Submarine Propulsion

Improved Submarine Performance (Boundary Layer control)

Torpedo Propulsion

FIGURE 6

MHD PROOF-OF-CONCEPT PROGRAM

	FY 88	FY 89	FY 90	FY 91	FY 92	FY 93
DOE/Industrial Plan	35	40.9	42.9	40.5	29.2	-
Actual	35	37	-	-	-	-
Revised Plan	35	37	47	40.5	29.2	-
Stretch-out	35	37	42.9	40.5	29.2	20

Mr. **Boucher**. Thank you, Dr. Coates. [Laughter.]
Mr. Peters.

STATEMENT OF LEONARD K. PETERS, VICE CHANCELOR FOR RESEARCH AND GRADUATE STUDIES, UNIVERSITY OF KENTUCKY, LEXINGTON, KY

Mr. **Peters**. Thank you, Congressman Boucher and other members of the subcommittee. I'm Len Peters. I am Vice-Chancellor for Research and Graduate Studies at the University of Kentucky. My testimony addresses the Department of Energy's non-nuclear R&D authorizations for oil shale research for fiscal year 1990.

Eastern oil shale is an enormous energy resource that will almost assuredly play a major role in meeting the energy and chemical feedstock needs of the nation in the 21st century.

It has been estimated that nationally this resource represents over 400 billion barrels of petroleum. Kentucky has an abundance of some of the richest of the eastern reserves. We have found the equivalent of over 16 billion barrels of oil in a narrow belt surrounding central Kentucky. This is equivalent to all of the oil in Texas and only includes shale that is on or near the surface and could be recovered easily with present-day technology.

Thus, Kentucky has much at stake in eastern shale and has, over the past decade, put much effort into its study. In 1980, we conducted along with two industrial partners the first thorough study of the economic feasibility of eastern oil shale development.

That study integrated technology assessment, mine design and resource assessment in a single effort. The focus of our work has been to develop a fundamental understanding of the chemical and physical characteristics of eastern shale as applied to processing and environmental concerns.

Very early, our researchers learned that eastern shale is fundamentally different from that found in the western United States. Thus, the processes which exist for western shale are not appropriate for eastern shale.

Our research in Kentucky on advance shale processing has contributed breakthroughs in the development of new technologies. A final spent shale which contains almost no residual carbon and sulfur should have no acid generating capacity has been produced.

We have demonstrated that KENTORT II, our technology, could completely recover the total energy potential of eastern oil shale while producing a spent shale with enhanced environmental safety.

A larger system is essential if development of the process is to continue. Scale-up would also enable evaluation of commercial materials of construction and sufficient crude oil would be produced for upgrading studies.

The proposed research for FY–90 is the most cost-effective plan possible for this process, consistent with reasonable development rate and meeting the necessary technical criteria. $375,000 is requested for this effort. We will add a large increment of support from the Energy Laboratory at the University of Kentucky.

New technologies such as KENTORT II will produce spent shales which are physically and chemically different than those in the past. In our opinion, the time to conduct research in this area is now, simultaneous with process development, when environmental solutions can be integrated into process design.

For the past five years, our researchers have been studying the environmental characteristics of retorted eastern oil shale produced from a conventional technology originally designed for western shale.

It is important that studies now be initiated on the disposal spent shale having the characteristics of that from advanced technology. The chemistry of the leachates generated under completely natural conditions will be determined over several seasons and the physical changes of the shale will be demonstrated.

Additional experiments will be conducted at the University of Wyoming indoor facility, which allows extreme weather conditions. It cannot be expected in a short duration field study.

Eastern oil shale, for that particular part of the program, we are requesting $355,000 to begin this research. Again, a large increment of support from the University of Kentucky will be added to this effort.

Eastern oil shale represents an enormous energy potential of national importance. Research should be conducted now by making modest investments over a longer period of time to support a stable research program.

We support an $8 million program for eastern oil shale research, which includes $4.5 million to continue the process development research at the Institute for Gas Technology; $2 million to continue novel process development research, including our KENTORT process; and $1.5 million for environmental studies for eastern oil shale research.

Funding at this modest level will enable research to be continued at several universities and laboratories across the nation with a goal of exploiting and utilizing eastern oil shale as a valuable source of liquid fuel.

Thank you.

[The prepared statement of Mr. Peters follows:]

Statement
for
House Committee on Science, Space, and Technology
Subcommittee on Energy Research and Development
by
Leonard K. Peters
Vice Chancellor for Research and Graduate Studies
University of Kentucky
Lexington, KY 40506

Madame Chairperson and Members of the Subcommittee:

My testimony addresses the Department of Energy's non-nuclear R&D authorizations for oil shale research for Fiscal Year 1990.

Eastern Oil Shale is potentially an enormous energy resource that will, with a very high degree of certainty, play a major role in meeting the energy and chemical feedstock needs of the Nation in the 21st century. It has been estimated that nationally this resource represents over 400 billion barrels of petroleum.

Kentucky has an abundance of some of the richest of the eastern reserves. Since 1980, we have drilled over 65 cores and completed tens of thousands of chemical analysis. Using rigorous standards, we have found the equivalent of over 16 billion barrels of oil in a narrow belt of twenty counties surrounding Central Kentucky. This is equivalent to all of the oil in Texas, and only includes shale that is on or near the surface and could be easily recovered with present day technology. These figures are much higher when considered in light of recent advances in oil shale processing.

Thus, Kentucky has much at stake in Eastern U.S. Oil Shale and has over the past decade put much effort into its study. In 1980, we conducted, along with two industrial partners, the first thorough study in the public domain of the economic feasibility of Eastern Oil Shale development. That study integrated technology assessment, mine design, and resource assessment in a single effort. Since then, the State of Kentucky has expended over $1.3 million dollars to co-sponsor, again with industrial partners, two pilot plant demonstrations of eastern U.S. shale. Kentucky has also developed and passed into statute a detailed set of environmental regulations for the mining of oil shale.

We have also provided a forum for Eastern Oil Shale research. For the past eight years, we have co-sponsored with industry, the Kentucky Department of Energy, and the U.S. DoE, the Eastern Oil Shale Symposium. Over 240 technical papers have been published from researchers world-wide from this symposium.

The focus of our work has been to develop a fundamental understanding of the chemical and physical characteristics of Eastern Oil Shale as applied to processing and environmental concerns. Very early, our researchers learned that Eastern U.S. Oil Shale is fundamentally different from that found in the Western United States. Eastern shale has a different type of kerogen, the solid material which generates the oil, and a different type of rock matrix.

Thus, the processes which exist for Western Shale are inefficient for Eastern Oil Shale. We also found that the standard techniques used for estimating oil yield of shale consistently underestimates that of Eastern Oil Shale.

Our initial studies concluded that advances in two research areas were critical to unlocking the energy potential of this resource. First, retorting technologies which are tailored to the unique characteristics of Eastern Oil Shale were needed; second, environmental research on the physical and chemical characteristics of retorted shale were necessary. Our experience in projects to commercialize oil shale earlier in the decade found that concern over the environmmental safety of the spent shale was the largest single impediment to the public acceptance of an oil shale energy industry.

Our research in Kentucky has contributed breakthroughs in the development of new processing technologies. In 1982, research at the Kentucky Center for Applied Energy Research discovered that the application of fluidized bed technology to Eastern Oil Shale pyrolysis resulted in yields much higher than expected. These findings were quickly confirmed at both the Lawrence Livermore Laboratory and at the Morgantown Energy Technology Center of the U.S. DoE.

However, the spent shale from fluidized bed processing was still high in sulfur and contained up to 50% of the original carbon as char. The sulfur can contribute to environmental problems in disposal, and the char represents wasted, unused energy. A long term program of research to solve these problems resulted in the formulation of the KENTORT II technology. This technology integrates three fluidized bed-based processing steps - pyrolysis, gasification, and combustion - into one thermally efficient process. In 1985 with additional support from the U.S. DoE, research to develop and prove the concept of this process was started using a small 5 pound per hour system.

In the unique KENTORT II process, recirculating shale from the gasifier provides the heat for pyrolysis, and 15-20% of the residual carbon left after pyrolysis is converted to a hydrogen-rich gas which can be used to upgrade the crude shale oils. Furthermore, the inorganic sulfur from the shale is removed as hydrogen sulfide; this can be converted to elemental sulfur. The removal of sulfur in this stage also reduces sulfur dioxide emissions from subsequent combustion. The final combustion stage burns the remainder of carbon from the shale to ultimately provide all process heat requirements.

The work of our researchers has proven the viability of gasification of pyrolyzed Eastern U.S. Oil Shale in a small unit. Up to 90% of the original sulfur has been removed, and as much as 20% of the starting carbon has been gasified at realistic temperatures and residence times. A final spent shale which contains almost no residual carbon and sulfur and should have no acid generating capacity has been produced. Thus, we have demonstrated that KENTORT II could completely recover the total energy potential of Eastern U.S. Oil Shale while producing a spent shale with enhanced environmental safety.

By the end of the current program in FY 1989, the research program for KENTORT II will have successfully proven many aspects of the process. A larger system is essential if development of the process is to continue. A completely realistic simulation of commercial-scale conditions is necessary using a larger system. With a six-inch reactor, 80% of the heat for the pyrolysis zone would be provided by recirculating char, and heat losses would be less severe. Scale-up would also enable evaluation of commercial materials of construction, and sufficient crude oil and spent shale would be produced for upgrading studies and environmental research. Also, oil shales from other eastern states could be tested.

The proposed research for FY 1990 is the most cost effective plan possible consistent with a reasonable development rate and meeting the necessary technical criteria; $375,000 is requested for this effort. We will add a large increment of support from the Center for Applied Energy Laboratory at the University of Kentucky.

New Eastern Oil Shale technologies, such as KENTORT II, will produce spent shales which are physically and chemically different from those of the past. In our opinion, the time to conduct research in this area is now, simultaneous with process development, when environmental solutions can be integrated into process design. For the past five years, our researchers have been studying the environmental characteristics of retorted Eastern Oil Shale produced from a conventional technology originally designed for Western U.S. Oil Shale. We focused on the geotechnical, leaching, and reclamation characteristics of the spent shale and used a field research station in Montgomery County, Kentucky for the work. The field station has large concrete holding tanks (lysimeters) where the elemental release or leaching characteristics of the materials is being determined.

Thus far, our researchers have found that the shale materials are capable of forming acidic drainage and could release envifonmentally sensitive elements. This has pointed out the need to further reduce the sulfur content of retorted Eastern Oil Shale to eliminate these hazards. Sulfur recovery was one of the key considerations in the development of the KENTORT II gasification stage. We also found that small laboratory tests cannot predict the behavior of materials under actual field conditions.

It is important that studies be initiated on the disposal of spent shale having the characteristics of that from advanced technologies. The fully instrumented field research site operated by our Energy Laboratory will be used to study retorted Eastern Oil Shale mined in southern Indiana. Large quantities of this shale was retorted under U.S. DoE sponsorship in a pilot plant and will undergo further processing by fluidized bed combustion. This material will be similar in nature to that produced from an advanced eastern oil shale process like KENTORT II and will be available in sufficient quantity for meaningful research.

The materials will be installed in the field lysimeters in a configuration that will duplicate a disposal pile. The chemistry of the leachates, generated under completely natural conditions, will be determined over several seasons and the physical changes of the shale will be documented. In later years, additional lysimeter experiments can be conducted at the University of Wyoming indoor facility. This unique installation allows extreme weather conditions that cannot be expected in a short duration field study.

A Systems Management Model approach will be utilized in this work which will make the information useable for other systems. The field data along with hydrologic, mineralogic, soil characterization, and mine and retorting technology information will be integrated into this computerized model. Thus, the impact of chemical changes of the spent shale will be assessed as will variations in disposal practices and spent shale utilization options. The model and the fundamental data generated will have applicability in the management of other energy related solid wastes including that from coal utilization. We are requesting $355,000 to begin this research. Again, a large increment of support from the University of Kentucky Energy Laboratory will be added to this effort.

Eastern oil shale represents an enormous energy potential of national importance. However, it is not as well understood as coal or Western U.S. Oil Shale. To realize its full potential requires research. This research should be conducted now by making modest investments over a longer period of time to support a stable research program. We believe in this approach, and for Fiscal Year 1990, we support an $8.0 million program for Eastern Oil Shale research which includes:

- o $4.5 million to continue the process development research at the Institute for Gas Technology.
- o $2.0 million to continue novel process development research; included in this is $375,000 for continued support of the KENTORT II technology development program.
- o $1.5 million for environmental studies for Eastern Oil Shale, including $355,000 for the initiation of spent oil shale disposal research.

I appreciate this opportunity to present my views and also for the previous support provided the Eastern Oil Shale program. Funding at this modest level will enable research to be continued at several research universities and laboratories across the Nation with the goal of exploiting and utilizing Eastern Oil Shale as a valuable source of liquid fuel.

PANEL 2 DISCUSSION

Mr. **Boucher**. Thank you, Mr. Peters.

Mr. Reid, let me begin the questioning beginning with you.

Several years ago, either you or another spokesman for the American Gas Association very strongly endorsed the Department of Energy's ERAB recommendations. This was the Energy Research Advisory Board. And that report was issued in 1987. It's entitled Geoscience Research For Energy Security.

Does the Gas Association still endorse those recommendations? And there's a second part to that question.

To the extent that they've been implemented, have they been implemented to your satisfaction?

Mr. **Reid**. In answer to the first part of your question, Mr. Boucher, yes, AGA and the gas industry do in fact support the recommendations of ERAB.

In answer to the second portion of your question, we certainly appreciate what has happened to date, but the funding levels that were recommended by the report still have not been achieved, particularly in the basic geosciences research support area.

And we would encourage the Congress to the extent that the budget permits to increase that funding progressively to the levels recommended.

Mr. **Boucher**. All right. Do you have any other comments with regard to the report's implementation? Or is it just based on funding levels?

Mr. **Reid**. The specific concern at this point about raising the funding level to permit total implementation of the program that was recommended. Right now, with the very limited funding available, the program is severely limited in application.

Mr. **Boucher**. What would you recommend as an appropriate annual funding level to enable the United States to have a stable gas research program?

Mr. **Reid**. Well, we've suggested a level for this year of $125.8 million. And that represents some increase. We think that represents a reasonable level. Obviously, there are opportunities to spend additional funding should it be available.

I think we have a greater concern at this point that lower recommended funding levels will have a substantial effect to inhibit what natural gas could potentially achieve in the energy economy of the United States.

Mr. **Boucher**. Could you take just a second to talk about some of the technological improvements that are going to be necessary to ensure that gas reserves are recoverable?

Mr. **Reid**. Well, there are several areas, and this is not an area of my specific expertise and I'd be happy to provide additional information, but basically the resources that we are looking to in the future are height sands resources, shale resources, geopressured methane. Essentially, all types of reservoirs that are difficult to produce energy from and specifically difficult to produce natural gas from.

There is a substantial need to evaluate techniques for drilling into those types of formations for enhancing the production from those formations, particularly in the case of geopressured methane, which, as I indicated in my testimony, is a very long-range, high-risk area.

But all of these areas need to be pursued to assure that there is an opportunity to fully develop the available natural gas resource base.

Mr. BOUCHER. And I would assume that the funding request that you're making of this Subcommittee is directed toward developing those very technologies?

Mr. REID. That is correct, and also obviously to maintaining and increasing levels of effort in utilization technologies to assure that the gas we can produce is used as efficiently and in as economically and environmentally sound a manner as possible.

Mr. BOUCHER. Okay. Thank you, Mr. Reid.

Mr. COATES. Let me pursue with you a couple of questions about the schedule for MHD research. Figure 6 in your handout forecasts what I interpret to be another four years of funding through the proof of concept stage. You're asking for $47 million this year; for FY-91, $40.5 million; $29.2 million for '92; and then it looks like $20 million perhaps for '93.

That may be an assumption but there is a stretch-out and that you not get the entire $47 million in 1990.

Mr. COATES. That's correct.

Mr. BOUCHER. So, assuming that you got $47 million this year, and I'm not sure you can assume that, do you then have a three-year program, or do you then have a four-year program?

Mr. COATES. If we get $47 million, then the program is completed on schedule in 1992.

Mr. BOUCHER. That's a three-year program at that point.

Mr. COATES. Three years.

Mr. BOUCHER. Now, that takes you through proof of concept. What about after that? We've heard testimony this morning that the Congress ought to be funding demonstration research as well as proof of concept research.

Are you going to be coming back asking us for demonstration funding after the end of that third year, or fourth year, depending on whether there's a stretch-out?

Mr. COATES. At the conclusion of this portion of the program, we'll then be in a position to proceed with retrofitting power plant.

There's two suggestions. One is in Montana, part of the Montana Power Company; and one is the Southern Company. Those designs are going forward.

That would be done under the Clean Coal program.

Mr. BOUCHER. Assuming that it's funded under that program.

Mr. COATES. I have confidence.

Mr. BOUCHER. Yes. Okay. So, at least it is not your current intention to be coming back to the Congress asking for demonstration funding. You're hopeful that you can get that funding under the Clean Coal technology reserve?

Mr. COATES. That's correct.

Mr. BOUCHER. Okay. We may see you back here.

Mr. COATES. Well, let me just follow up on that. The plan is to retrofit an existing power plant with an MHD unit. So there are a variety of ways to cost-share that.

And, in fact, Bob Labrie, former Executive Vice President, Montana Power Company, is heading a committee which is currently looking into ways to raise the money for the retrofit.

Mr. **Boucher**. Are you getting any private sector contributions now?

Mr. **Coates**. The MHD program this year is cost-shared 25 percent by the private sector.

Mr. **Boucher**. Is that an increase or a decrease over the private sector contribution in prior years?

Mr. **Coates**. No, under the law, it increases each year. Last year, 20 percent. The year before, 15; and 10. Next year—by the time, if this program stays on schedule, by 1992, it will be close to 50 percent.

Mr. **Boucher**. And do you anticipate getting that private sector funding?

Mr. **Coates**. Well, we have not had any difficulties.

And I would also suggest to you, Mr. Chairman, if you were to look at the Department of Energy's cost-sharing programs, I don't think you'll find any technology at this state of development that is cost-sharing anywhere near the MHD program.

And the other thing to consider is that many of the programs which are being cost-shared, and rightfully, are really second and third generations of existing technology.

This program is being developed by many, many companies, not one of which can expect to really see a return for many years. Utility companies and the A&E companies.

Mr. **Boucher**. Let me just pursue a practical question with you, and I have a little bit of a parochial interest in asking this.

My understanding is that once you get the MHD technology up and running, the fuel source will be gas, at least in the short-term. Longer-term, you're hoping that the fuel source will be coal.

Correct me if I'm wrong in making that assumption.

Mr. **Coates**. No. This program in the United States has always been directed toward coal. At the present moment, a coal combustor is being designed and built for testing power train. The whole program will be coal.

Mr. **Boucher**. All right, that's comforting to hear coming from a coal-producing region.

Let me just ask a very practical question about coal consumption in association with the project.

Compare, if you will, the tonnage of coal required per Btu under MHD to the tonnage that's required per Btu by direct coal combustion in a traditional coal-filed facility.

Mr. **Coates**. Well, when fully developed, the plants will be operating at 60 percent compared to, say, about 35–40 percent. So you'll be extracting 60 percent more energy out of a given ton of coal than will the current power plants which are operating at 38 percent.

Mr. **Boucher**. Okay. I'm not sure I entirely understand the question.

Let's assume a standard efficiency for the power plant, but take—let's take 10 tons of coal just as an example. If that will produce X-number of Btu's today in a traditional coal-fired power plant, how many Btu's will that produce in an MHD plant?

Can you tell me that?

Mr. **Coates**. Could I ask Dr. Owens?

Mr. **Boucher**. Sure. That's fine.

Mr. **Coates**. Could you answer that, Bill?

Mr. **Owens**. My name is Bill Owens. I'm with Gilbert Commonwealth. If I understood it correctly, you were asking if for a given amount of coal, what difference in power extraction in——

Mr. **Boucher**. That's correct.

Mr. **Owens**. As Mr. Coates pointed out to you, in the key system, it is expected to have an efficiency 50 percent greater than a conventional plan. So per ton of coal, you'll be able to extract twice the amount electricity of what you're doing.

Mr. **Boucher**. Okay. Well, that's a very informative answer. So, to get an even level of power, half the coal would be required? That's very efficient. It may not exactly thrill the coal economy, I suppose.

Well, that's very helpful. Thank you, Dr. Coates.

Mr. Peters—I'm still referring to you as Dr. Coates, you know.

Mr. **Coates**. It will probably be the only time. [Laughter.]

Mr. **Boucher**. Actually, I think in the years that you have educated this panel, all of us probably deserve doctor degrees now, too. [Laughter.]

Mr. Peters, let me ask you if there are any significant environmental problems that you think will be associated with oil shale development and to the extent that they exist, could you identify them?

And it's my understanding that the research funding you're requesting would be devoted in some measure to helping to resolve those and to forecast ways they can be resolved.

Mr. **Peters**. That's correct. What we're trying to do with the combined program of process development and evaluation of the potential for environmental concerns with eastern shale is basically design an environmentally compatible process.

The process development is not static at this particular point in time and we're early enough in the process that when we see the problems that could be potentially damaging to the environment, we have the ability to modify the process to take that into account.

This has already been done. We have been able to reduce the amount of sulfur in the spent shale considerably; The amount of carbon left behind, considerably. So it's a feedback process where we use the results from the environmental experiments to adapt the process to make it more environmentally compatible.

Mr. **Boucher**. All right, thank you very much.

Can you give me some idea of over what length of time the funding level that you're asking for, some $8 million annually, would be appropriate?

Mr. **Peters**. For the entire eastern shale program, I can speak more directly to the work that we're dealing with. Leave me answer that first.

In our KENTORT process development work, we see about a three to five year development cycle for that particular new advance technology. Certainly, as we get closer to the 21st century, I think we're going to see oil shale as being something that is more significant in terms of an energy resource. I think eastern shale is going to increase in importance in that particular part.

So I would suspect that particular funding level should be going up if we are really going to try to exploit eastern shale, as well as western shale, as energy source.

Mr. BOUCHER. Did I hear a number of years mentioned?

Mr. PETERS. Well, I was talking specifically about the development process for our technology. Okay?

And that's about a 3- to 5-year development process. But, for oil shale in general, and I think we're going to become much more dependent on it, when we get to 2010. I think then that we're going to have to be looking at more money spent in oil shale development work.

Mr. BOUCHER. All right. Thank you, Mr. Peters.

Mr. Smith.

Mr. SMITH. Thank you, Mr. Chairman. I appreciate the questions that you've already asked and really only have one additional question, for Mr. Reid. And I ought to preface the question by warning Mr. Reid that our chairman may want equal time when you finish. But I still want you to take as much time as you need.

And that is what are the relative advantages of natural gas over other types of fuel as a source of energy?

Mr. REID. That's kind of a broad question.

Mr. SMITH. Now, you can either go at it from the environmental concerns, you can go at it from efficiency, you can go at it from abundance, you can go at it from any number of directions that you want to.

Mr. REID. Thank you for the help on the answer, Mr. Smith. [Laughter.]

One of the things that I was thinking this morning as I listened to some of the earlier testimony is that there is a lot of technology in the DOE research program which is aimed at the use of coal and other fuels more efficiently. And all of that technology appears to be aimed at the longer-term future.

I think natural gas also has a very strong and potentially a very much larger place in the long-term future because of its abundance, because of the fact that it is a clean-burning fuel and because of its flexibility in application.

But I think one of the key points I would choose to make in response to your question is that natural gas also offers a major opportunity in the short-term to allow the United States to begin alleviating some of our environmental problems, for example, by coal-firing coal with natural gas, by converting vehicles, particularly in the early stages heavy duty fleet vehicles for operation on natural gas as opposed to diesel fuel to minimize particulate emissions.

And also, as was indicated earlier by Assistant Secretary Wampler and by Dr. Markowski, as the initial stages, the initial fuel, if you will, for early commercialization of some technologies such as combined cycle power plant for electric power generation, and also fuel cell, particularly the early introduction of the phosphoric acid fuel cell technology. It's the 200 kilowatt size which will be a natural gas power plant. And also probably the early market introduction of molten carbonate fuel cells, which could also be fueled with natural gas pending the development of satisfactory coal gas fires.

Mr. **Smith**. Anything else? That's a good start.

Mr. **Reid**. Thank you.

Mr. **Smith**. I happen to be biased in your direction.

Thank you, Mr. Reid.

Mr. Chairman, I don't have any other questions.

Mr. **Boucher**. Thank you, Mr. Smith, and, gentlemen, we thank you for your illuminating remarks today and for your prepared statements. We'll consider them in due course as we evaluate the Department of Energy's fossil fuel research budget for FY-90. We appreciate your being with us.

That concludes the work of this Subcommittee for today. The Subcommittee stands adjourned.

[Whereupon, at 11:54 a.m., the Subcommittee adjourned, to reconvene, subject to the call of the Chair.]

APPENDIX

Additional Material for the Record

STATEMENT
OF
DONALD R. GLENN
VICE PRESIDENT
ENERGY RESEARCH CORPORATION
DANBURY, CONNECTICUT

TO THE

HOUSE OF REPRESENTATIVES
HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
MARILYN LLOYD, CHAIRMAN

HEARINGS
ON THE
DEPARTMENT OF ENERGY - FY 1990 BUDGET REQUESTS
FOSSIL ENERGY: FUEL CELLS
CONVERSATION: ELECTRIC AND HYBRID VEHICLES

FEBRUARY 22, 1989

Statement by
Donald R. Glenn
Vice President
Energy Research Corporation

The Energy Research Corporation (ERC) is a world leader in developing advanced batteries and fuel cell technologies for power generation and electrical energy storage. We are making excellent progress on several programs that will result in equipment that will convert abundant U.S. energy resources into the premium fuel, electricity. These products operate silently, absent of noxious odors, and with significant reductions in global warming-linked CO_2 emissions, and acid rain precursors (NO_x,SO_x). Most importantly, this power will be produced at the highest electrical efficiencies obtainable by any technology.

With the passage of the Reagan Administration, we are heartened at the choice of our new Energy Secretary, James Watkins. We hope he has the mandate by President Bush to move this country out of the present energy and environmental morass. His credentials and forthright management style are a most welcome change for the better. We wish him every success and hope that the adversarial relationship between past DOE executives and the Congress is replaced by a cogent, positive, and unified energy agenda in the years ahead.

The following sections review the status and our outlook on our major research programs, all containing shared-costing positions between the government, ERC, and other private sponsors. Despite the vulnerability of being prejudiced, we are convinced that these advances are important and may be critical to help satisfy our country's coming electricity needs in their unique ways. As generation capacity reserve margins disappear with few new large capacity additions and lethargic replacement of retired power plants, the use of alternative generation and load management options will become a major priority. Thanks to enlightened Congressional energy authorization and appropriation committees and staffs, many valuable energy R & D capabilities have survived the '80's, albeit barely, to where payoff to the nation in the mid-1990's can be realized. ERC is proud to represent a leading edge for the U.S. in some of these areas.

Direct Fuel Cell (DFC)

The DFC Program achieved its most significant milestone to date during 1988. Most importantly, all the stack components were scaled-up to 4 sq. ft. This is ERC's full-sized hardware entry for a commercial market. During 1988, ERC built and successfully operated two full-area short stacks directly on methane, each rated at 2 kW. A third full-area stack rated at 5 kW was also operated in our new test facility. This stack, built with private funds, has exhibited remarkably stable performance for over 2000 hours, meeting all design levels for cell voltage , resistance, and projected decay. The full-size components were manufactured using techniques directly related to planned mass production processes.

Based on a 1985 detailed system study of technical and economic issues which was subsequently refined and revalidated, ERC has defined a "standard" stack (100 kW) consisting of 5 modules of 60 cells each. Again with private funds, ERC has built, and is now testing, a full height 60 cell subscale (1 sq. ft.) stack module. This will confirm the overall stack module design in terms of seals, mechanics, and manifolding. During the year (1989), a full-scale, full height (4 sq. ft. active area, 60 cell) preproduction, prototype stack module will be built and tested on methane at ERC's new test facility now under construction.

As should be evident, DFC progress is rapidly approaching a first system-level trial. In fact, ERC has defined a stand-alone unit capitalizing on the 100 kW "standard" stack as the centerpiece of the test hardware. Predicated upon continued success, ERC will deliver a number of units in 1991-2 to host sites for their evaluation of the DFC system. During this period, our facility will be upgraded with pilot plant production equipment to verify the selected manufacturing processes and to develop automated quality control and inspection systems.

At no time have the advantages of fuel cells been more needed than the present. Controversies abound over atmospheric carbon dioxide and global warming, acid-rain pollution, better utilization and conservation of our premium fossil fuel source, natural gas, and clean utilization of coal. The DFC answers these issues uniquely and undeniably, without competition. The DFC has a natural gas system electric efficiency capability of 55%-65% depending on plant size. Costs of electricity (COE) range between 4.5¢-5.5¢/kWh using coal fuels and about 6¢/kWh using natural gas priced at $4/mmBTU. This fuel cell stands alone among currently available or emerging new generation options. Carbon dioxide emissions from DFC natural gas power plants will be two-thirds or less that of coal fueled combustion plants. Those advantages, as well as reduced energy costs to millions of American consumers, can be achieved by the use of the DFC system.

For first markets this technology will utilize natural gas and other methane-containing gaseous fuels. As coal gasification becomes available, all the above-mentioned benefits will enhance coal uses in generation applications either as a dedicated fuel source or interchangeable with other fuels increasing the system availability and reliability. In fact, ERC believes that future Clean Coal Technology (CCT) projects should recognize the value of demonstrating gasification technologies able to produce fuel gases rich in chemical energy; that is, products containing methane fractions. In general, these coal conversion processes are more energy efficient and operate at lower temperatures and pressures. When integrated with the DFC, the overall plant will yield lowest cost electricity and high availablilty with environmentally friendly emissions.

ERC has attracted significant private sector support for our coal-fueled MCFC and DFC projects. However, strong and continued Federal support is required. The optimism inherent in this statement should not be interpreted as if these fuel cells are approaching close-out status. If this generator is to be ready for the coal-gas energy resource, much works remains. We need to extend stack survivability and life under the harsher chemical environments of coal gas fuels. In the interim, natural gas-fueled units can and should be built, tested, and installed in selected field experiments. Through these field trials, potential markets will gain "hands-on" experience. The manufacturers will receive valuable, practical feedback in operating and servicing regimens, support equipment, training requirements, and other market/customer needs. The customers will gain confidence in this technology by seeing larger units in operation.

Current electric utility demand forecasts are trending upward from predicted electrical growth rates of just a few years ago. At the same time new generation capacity is not being installed. Concurrently, as mentioned earlier, serious environmental consequences loom with the continued employment of combustion-dependent generation schemes. A significant near-term (1990's) impact can be obtained by setting a high priority, technically and financially, to bringing the MCFC/DFC option to commercial readiness as soon as practicable. This Congress and Administration can claim this as an accomplishment. Send our nation and the world the long-needed message that the U.S. is doing something significant and measurable in resolving the immediate problems of environment improvement and energy conservation.

To this end, ERC urges that the current contracts due to end January, 1990, be extended to FY 1991 with no contract or funding disruption. The pace of the progress now underway would be seriously impeded to attend to bureaucratic pressures to respond to a nonessential, but major, PRDA exercise. With a large number of foreign countries and firms engaged in well-funded, multi-year molten carbonate fuel cell development efforts (7 years in Japan, 5 years in Italy, and 3 years in Holland), perturbing the few U.S. programs will further jeopardize the already marginal lead we now enjoy. This is not the time to self-destruct by placing impediments in the path of the few U.S. teams involved.

Nickel-Cadmium EV Battery

The ERC nickel-cadmium (Ni-Cd) battery technology links a superior alkaline electrochemical couple with a novel electrode construction technique, a roll-bonded, non-sintered plate. The result is a high efficiency (70%), lightweight (half that of lead-acid batteries), and more compact (40% less volume than lead acid) product. What this new battery does is to allow more capacity (stored energy) to be placed on board the vehicle in order to extend the EV range proportionate to the weight/volume savings over today's baseline battery, the tubular lead-acid system.

Numerous significant accomplishments have been produced as the nickel-cadmium EV battery program moves ahead. Each of the reported points below marks a new frontier in EV battery progress.

By introducing additives and new preprocessing treatments to the electrode materials, ERC scientists have tested and verified that our EV battery endurance is over 1200 full discharge cycles. In other tests where an urban driving pattern is simulated, the battery has shown the capability of providing over 45,000 miles. Relating these two findings, the ERC battery installed in a compact-sized car used for a daily job, commuting a round trip distance of about 35 miles, will last at least four years.

In previous statements ERC recognized the importance of a maintenance-free battery, particularly as regards replenishing lost water from the electrolyte. Two paths were defined: by minimizing the loss through chemical recombination of the evolved gases (hydrogen and oxygen) to form water, and by sealing the cells to contain these gases. Both approaches have shown positive results. In fact, half-scale sealed

Ni-Cd cells (100 Ah) have accumulated over 220 cycles in continuing tests. Other promising improvements still being evaluated are a significant reduction in electrode "swelling", a unique and undesirable Ni-Cd characteristic, and improved calendar life to about 10 years.

The additional lower level of effort will finalize most of these issues producing a first generation prototype Ni-Cd EV module suitable for field test in DOE/EPRI/EVDC vehicles. This technology is probably the successor to the advanced lead acid system. The new Ni-Cd battery will improve range, life, and performance to bring EV's closer to market-required expectations.

Fuel Cell/Battery Powered Bus

The appearance on our streets of an urban mass transit vehicle that does not belch out smelly, dirty exhausts, nor require earplugs to be spared the loud diesel groans as the bus lumbers away from the stop, is a worthy objective. This is an "EV" we can all appreciate! An added bonus is that it can use methanol, a non-petroleum dependent transportation fuel.

The ongoing phosphoric acid fuel cell (PAFC)/battery hybrid power system development - Phase I is providing the hoped-for assurance that these power sources can be integrated and satisfy the urban bus mission. Using an ERC-donated 7 kW PAFC system and a suitably matched ERC nickel-cadmium battery (4½ kWh), operations simulating an urban driving schedule of stop-start and acceleration/hill climbing loads confirm the feasibility of this new concept. Several bus and propulsion drive designs have been defined using off-the shelf hardware. Preliminary findings are that acceleration, speed, and life by the hybrid system are within the DOT standards currently used for bus procurements. Higher first costs than diesel power systems are projected. However, when energy efficiencies of more than twice that of combustion systems, simpler maintenance tasks, and fewer spare parts are considered, system life cycle costs should be very attractive.

We are optimistic that the air-cooled, all-gas PAFC and lightweight nickel-cadmium battery are most responsive to the program objectives. As an aside, the battery is a spin-off of the Ni-Cd designs for EV's being developed under another cost-shared effort with the DOE. In fact, data resulting from early testing is benefiting both efforts. The bus usage stresses peaking power discharges, and rapid charging, while the conventional EV mission requires a steady discharge and overnight recharge. Voltage matching and power control management are key issues in the system design. The air-cooled PAFC and Ni-Cd cells exhibit fortuitously compatible electrical performance resulting in a straightforward controller interface between these power sources and the bus drive train.

In the coming months, ERC will build a half-scale, fully automatic system with driver controls and monitors. Following a three month, in-depth series of tests, a final report will mark the completion of Phase I. At this juncture, there are no known technical impediments to fielding the test bed bus in Phase II. We believe that the program is sound and success oriented. In fact, there are several other mobility applications awaiting the outcome of the vehicle tests to further this system concept.

This program is important for another reason. ERC is the last remaining American company actively involved in building small capacity, fully automatic PAFC systems. PAFC contractors supported by the Fossil Energy Division are pursuing a variety of utility applications from 200 kW to megawatt-sized systems. The fuel cell/battery bus program recognizes that there are opportunities well below the 200 kW level that can benefit from PAFC systems in non-utility niche markets. With the increasing environmental controversies and dramatic contrasts offered by this clean, quiet, new power system, we believe the test bed bus program (Phase II) should go forward so this option can challenge diesel power in urban settings.

We would like to recognize and applaud the new fuel cell commercialization initiative introduced by the American Public Power Association (APPA). Entitled "Notice of Marketing Opportunity", this endeavor asks that the fuel cell developers/manufacturers define their marketing-oriented plans and describe what the APPA (and others) can do to ensure a successful outcome. They expect to provide financial and organizational support for showcase projects and private sector awareness programs. It is this kind of forward-looking scenario by those who realize the important contributions fuel cell power plants offer that can make an impact. The government can further catalyze this APPA undertaking by adding needed support in the outyears when selected projects (in 1989) are begun.

Concluding, and returning to the opening theme, it should be evident that each of these programs offers important new power options to our country and our shrinking world. We at ERC enjoy a reputation for technical excellence and integrity in promoting these activities, backed by our strong cost-shared commitments. The case we plead is that first field trials be encouraged and funded through an objective series of government/industry partnerships where the word "demonstration" is accepted as the reward for R & D well done.

STATEMENT BY BERNARD S. LEE
PRESIDENT, INSTITUTE OF GAS TECHNOLOGY
HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
February 22,1989

This year, the two most widely publicized and critical issues facing the energy industry are environmental: cleaning up nuclear waste and assessing the impacts of global air pollution. We may not yet know the magnitude of these problems, but we know their solutions will be costly.

This Subcommittee has a difficult challenge. While the problems of the nuclear industry and our resurgent reliance on imported oil remind us of the importance of our vast domestic supply of fossil fuels, the environmental warnings of acid rain and other air pollution problems help focus the task of finding ways to use fossil fuels more cleanly. This Subcommittee has shown excellent leadership in directing energy research for the future, but the growing constraints of budget pressures will make all decisions more difficult. Energy research may clearly have been one of the fields President Bush had in mind in his inaugural address when he reminded us having "more will than wallet."

At the same time that the needs and costs of energy research are growing, the days of a broad-brush approach are quickly passing. While the very nature of the federal role in research involves high costs, high risks and long lead times, researchers know that the Congress is under increasing pressure to show constituents that you are investing in sound ideas that will move us toward a cleaner, more stable energy supply at the lowest cost. Although we cannot come to you with guarantees, the research community, through its recommendations to this Subcommittee, must help focus the search for sound future energy technologies.

We all must ask tougher questions. How will research lower the costs of a technology? Are we making it a cleaner source of energy? What will it cost--and over how many years--to refine it for commercial use? Although we have learned that there may be no single, perfect fuel or technology to meet all our future energy needs, how many options do we need, and how do we select among them? And will we end up with products that will be useful, or will they only sit on a shelf, technically perfected but unusable or unattractive for transfer into commercial application? We all need to learn carefully from the lessons of the nuclear industry, both in assessing the real costs of a technology and in assessing the levels of proof and certainty that end users of our technologies will require in the future. Costly lessons of unfinished nuclear power plants have made rate payers angry and shareholders nervous. At the same time federal budget pressures are forcing stronger emphasis on private cost-sharing, investors are seeking higher levels of development and confidence before committing funds. Utility and industry executives may require stronger assurances and lower risks, demanding that the federal role in bringing technologies to "proof of concept" or "commercialization" be extended to more costly and complex levels.

IGT is proud of its work. As a private laboratory, we hope we add to the constructive diversity of ideas this Subcommittee must funnel into a comprehensive package of research. Our recommendations focus on improving the efficiency of developing technologies, lowering the costs of commercialization and addressing environmental concerns. We have involved private industry in planning and developing many of our projects, helping to ensure their commercial applicability.

Before discussing the IGT projects and recommendations in more detail, I would point out that IGT strongly supports the positions and recommendations of the gas industry. We agree that an Assistant Secretary for Natural Gas should be appointed, and that the total federal gas research efforts should be funded at $125.8 million for FY90. Those recommendations present a very useful and workable research program to advance current technologies.

Within the gas industry recommendations, IGT specifically recommends the following:

FUEL CELLS:

IGT's IMHEX molten carbonate fuel cell (MCFC) design is one of three current approaches in an on-going DOE effort to develop a molten carbonate system. The IMHEX concept's unique internal manifold offers design and cost advantages. IGT has made significant progress in developing the IMHEX system, and is ready to move to developing cost-effective scale up and testing long-term operation and performance of stacks. In order to keep advancing all three current, technologically distinct, MCFC projects,

IGT recommends $24.0 million to be evenly divided among the three existing MCFC contractors for development, scale up, manufacturing, endurance and large scale component testing.

In addition, there is a need for continued technology base research to provide testing and technical information useful to all three existing MCFC efforts. To support this needed base research,

IGT recommends $1.0 million to expand technology base research including the continuation of existing contracts for alternative anodes and corrosion prevention.

IGT has also begun work, under DOE contract, on a solid state proton conductor (SSPC) fuel cell, a novel, advanced fuel cell concept. Work on the SSPC will also provide valuable information on the potential uses of perovskites, a new class of ceramic materials. For this work,

IGT recommends $0.5 million to continue the evaluation and development of the Solid State Proton Conductor Fuel Cell.

COAL BED METHANE:

Significant amounts of natural gas were generated and trapped as our vast coal resources were formed. To recover that methane, greater study of the geoscience of coal beds is needed, developing greater knowledge of the retention of gas in various types of coal and the ability of trapped methane to move through coal seams at a rate that would support commercial production. To provide that base of knowledge,

IGT recommends $1.0 million for a joint geoscience research effort with IGT, the University of Alabama, and the West Virginia University, to determine the relationship among

coal type, grade and rank, and geology and recoverable methane from a wide range of coal beds to allow the maximum production of natural gas.

COAL:

In order to expand the clean use of our vast coal resources, a team headed by IGT is working under DOE contract to develop a mild gasification process to convert coal to marketable, value-added products. To determine economics and environmental and technical performance, and produce product for manufacturers to test, it is necessary to advance the IGT mild gasification process to the design, construction and operation of a 24 ton/day, mine-mouth process demonstration unit. To advance this work,

IGT recommends $0.4 million for the completion of the initial IGT mild gasification test program, and $3.0 million for initiating the design and procurement of long-lead items for a cost shared 24 ton/day PDU based on the IGT concept.

We also recommend two programs that are in addition to the gas industry recommendations:

Development of cleaner, more efficient and more economical coal combustion systems is also essential for future coal use. IGT has invented an advanced, two-stage coal combustor capable of either atmospheric or pressurized operation, making it adaptable for retrofit or in new combined-cycle power plants. The first stage uses a fluidized bed to remove sulfur and limit NOx production, and the second stage, a cyclonic combustor, combusts remaining gases and separates solids to increase environmental performance and energy efficiency. To advance this work,

IGT recommends $1.0 million to develop an advanced two stage coal combustor based on IGT's sloping grid fluidized bed and cyclonic combustion technology, using existing PDU facilities.

EASTERN OIL SHALE:

With cost-effective production technology, Eastern oil shale could be a significant addition to our domestic energy supply. The necessary mining infrastructure and water resources are available for production, and the Eastern United States offers a close and ready market for liquid fuel products.

Retorting eastern oil shale in the presence of hydrogen has dramatically increased the yield of oil. A team led by IGT has been advancing this concept under DOE contract, developing a new technology known as pressurized fluidized-bed hydroretorting (PFH). The team is also developing technologies and processes to lower the cost of the PFH process, and is ready to test this process on a range of eastern oil shales. To continue this work,

IGT recommends $3.0 million for continued development of the PFH process, using a foil membrane in hydrogen production and a carbon dioxide methane mixture in shale oil upgrading, and$1.5 million for design and engineering of a 4 ton/hour transportable PFH process development unit.

In the area of novel concepts, the KENTORT II system, an inert-gas, atmospheric-pressure fluidized-bed retort system being developed by the University of Kentucky Center for Applied Energy Research (CAER), has show significant improvement in oil yields over conventional technologies. It also produces valuable chemical by-products and decreases environmental problems associated with spent shale disposal. Results so far from a 5 lb/hour integrated reactor system are very encouraging, but scale up is necessary to better simulate performance at a commercial level and to produce larger quantities of shale oil and spent shale for testing.

IGT recommends $2.0 million for continuing novel concepts research on Eastern Oil Shale including efforts to extend the data base for the KENTORT II process.

Assurances of environmental quality and safety are essential for implementing an oil shale industry, and the University of Kentucky CAER has been operating a field research station to study the environmental effects of retorted, spent oil shale. The application of a Systems Management Model to both field data and controlled laboratory conditions will allow careful assessment of spent shale disposal practices and utilization options.

IGT recommends $1.5 million to conduct environmental studies on Eastern Oil Shales which would include University of Kentucky efforts to assess mitigation of the impacts of retorted, spent shale.

BIOFUELS

Conventional single-stage anaerobic digestion, used by many industries and municipalities as a solution to solid waste disposal, produces a product gas that is 60% methane and 40% carbon dioxide. Improving that gas to the 95% methane level needed for pipeline quality has been expensive. Application of pressure swing absorption techniques for gas purification can eliminate this costly step. Use of two stage anaerobic digestion instead of single stage will eliminate chemical costs and will allow the use of smaller and more economic equipment because of higher reaction rates. Integrating pressure swing absorption with two stage anaerobic digestion promises to be the most economic means of producing pipeline quality methane gas from solid waste or biomass.

IGT recommends $0.5 million to develop an integrated pressure-swing two-stage anaerobic digestion system based on the GRI concept using an existing PRU to economically produce pipeline quality methane from solid waste and biomass.

Another alternative to solid waste disposal has been incineration. Some mass burn technologies have used refuse derived fuel (RDF), removing non-combustibles from municipal waste to create a fuel that can be used alone as a fuel or as a supplement to coal in boilers. Use of RDF, however, has been hampered by unfavorable economics. IGT's RENUGAS process, a pressurized, fluidized-bed process for the gasification of biofuels, can be applied to RDF in a highly efficient, environmentally sound manner, eliminating the release of harmful emissions or the creation of dioxins while achieving power generation efficiencies up to 45%. The process can also be used to produce a synthetic gas to be converted to methanol. RENUGAS combined cycle power plants can also be economically built in a wider range of sizes than most mass burn facilities, making the technology available to a broader range of users.

IGT recommends $1.5 million to apply the RENUGAS technology and IGT's existing process research unit to the gasification of RDF, directed toward both electric power and methanol production.

GREENHOUSE EFFECT:

Photosynthesis is a natural process for recycling and fixing carbon dioxide, and hydrocarbon-producing algae are very efficient in that process. Current algae systems bubble carbon dioxide through shallow ponds, requiring large surface areas and limited to daytime operation. IGT proposes that carbon dioxide from a fixed point source such as a power plant can be scrubbed to produce carbonate or bicarbonate solutions, a more readily usable and efficient carbon dioxide source for algae. In an attached film reactor (AFR), a thin film of algae will be attached to an inclined surface and sprayed with the carbonate or bicarbonate solutions. The spray will feed the algae as well as wash mature algae and the hydrocarbons that have been produced into collection facilities for separation and use. This system will allow continual carbon dioxide control and will reduce land requirements by an order of magnitude.

IGT recommends $0.5 million to produce a more active algae and evaluate the attached film reactor concept using carbonate and bicarbonate solutions as a means of reducing carbon dioxide released to the atmosphere from point sources.

This concludes my testimony. I have submitted more extensive fact sheets and summaries for these recommendations, and I would be happy to answer any questions or provide further information for members of this Subcommittee.

This concludes my testimony. I have submitted more extensive fact sheets and summaries for these recommendations, and I would be happy to answer any questions or provide further information for members of this Subcommittee.

MOLTEN CARBONATE FUEL CELL STACK PROGRAM

An integrated coal gasifier/molten carbonate fuel cell power plant can use abundant domestic coal to produce electricity at an efficiency approaching 55% compared to 33% for conventional systems and 45% for other advanced electric power generating technologies. It will achieve this with lower carbon dioxide emissions, negligible sulfur and nitrogen emissions, and at potentially lower cost than other competitive technologies.

A fuel cell takes in fuel and air or oxygen and directly produces electricity by means of an electrochemical reaction. The fuel cell's modular nature allows its use in a wide range of sizes and applications, from a few hundred kilowatts to multimegawatts, and from small on-site natural gas fired cogeneration systems to coal gas fueled baseload utility power plants.

The Department of Energy is supporting the development of three molten carbonate fuel cell (MCFC) concepts. Each of these concepts is different and all are in the developmental stage. While it is too early to determine the commercial viability of the three approaches, early analyses are very promising.

The IMHEX^{tm} concept developed by IGT is designed and engineered to take advantage of IGT's extensive knowledge in MCFC technology, and has addressed and resolved many of the technological difficulties faced by the MCFC community. IMHEX is the only internally manifolded approach being developed in the U.S. This approach gives advantages in ease of cell assembly, method of charging the electrolyte, carbonate management, and efficiency of cell sealing. The separator plate and all active components are designed to allow for cost effective manufacture.

The current IGT stack test program has successfully demonstrated the viability of the IMHEX concept. No problems have been experienced in carbonate management or with the stack adapting to the changes in stack dimensions which occur during the operation of all MCFC stacks.

Additional developmental efforts are needed on the IMHEX concept to:

- improve tolerances in the manufacturing operations;
- scale up component manufacturing and stack testing from 1 ft^2 to full size; and
- improve component endurance to achieve a 40,000 hour stack life.

In addition to the three stack development contracts, DOE should have separately contracted technology base efforts addressing concerns common to all MCFC approaches.

IGT recommends $24.0 million to be evenly divided among the three existing MCFC stack contractors for development, scale up, manufacturing, endurance and large scale component testing. IGT also recommends $1.0 million to expand technology base research including the continuation of existing contracts for alternative anodes and corrosion prevention.

SOLID STATE PROTON CONDUCTOR FUEL CELLS

The Department of Energy initiated a contract with the Institute of Gas Technology in mid FY88 to evaluate the potential of high temperature proton conducting materials for use as a novel advanced fuel cell.

This long term, high risk program is expected to result in a solid state proton conductor (SSPC) fuel cell that has superior efficiency, cost and life over other emerging power generating technologies. In the SSPC, water, a product of the electrochemical reaction occurring in any fuel cell, will leave the fuel cell with the oxidant, and not with the fuel. This prevents the fuel dilution that occurs in solid oxide fuel cells and produces a higher electrical generating efficiency. Because it is a solid state device, the SSPC will have low maintenance, high performance and long lifetime. It is also expected to have high tolerance for contaminants in the fuel.

The SSPC will use a new class of ceramic materials, perovskites. The results of this project will determine the potential for this class of materials to be used in new highly efficient devices and sensors such as hydrogen pumps, hydrogen sensors, membrane separators for gas separation, and electrolyzers to produce hydrogen from water.

IGT recommends $0.5 million to continue the evaluation and development of the Solid State Proton Conductor fuel cell.

COAL-BED CHARACTERIZATION FOR ENHANCED METHANE PRODUCTION

Significant amounts of natural methane gas were generated and trapped as coal was formed. An estimated 300-500 TCF of this trapped gas is recoverable. Historically, coal bed methane was vented to the atmosphere to reduce the safety hazards in coal mines. A small amount of coal bed methane is now being produced commercially from a limited number of reservoirs.

Methane is not uniformly present in all coal beds. Two scientific factors are critical for its economic production. First, significant quantities of gas must have been generated and trapped to form a reservoir. Second, the gas must be able to move through the coal at flow rates sufficient to support a commercial well. Better knowledge of both of these factors is necessary to evaluate and recover the maximum amount of natural gas present in the extensive U.S. coal resources.

Two distinct but related topics are important when considering where coal bed methane would have been formed and subsequently trapped. These are:

- the relationship between coal type and rank and the composition and quantities of volatile substances, and
- the influence of coal grade and type on the retention of gas in the coal bed.

Work at the School of Mines and Energy Development at the University of Alabama has shown that relationships among coal composition, rank and gas content can be recognized in Alabama coals. Expansion of these studies to a wide variety of coals in various coal basins throughout the U.S. would improve the predictive value of the correlations. The West Virginia University will perform mechanistic correlations relating coal properties and gas content and producibility.

The flow rate of gas through a coal seam depends on the physical properties of the natural fractures present in the coal, as well as the sensitivity of the fractures to increased stress as gas is produced from the seam. The Institute of Gas Technology has developed and applied specialized techniques to study the geological properties affecting the productivity of various tight gas reservoirs. A better understanding of the geoscience of coal bed methane production will lead to the improved predictability of the production potential of these resources and will increase the recovery of domestic coal bed methane gas.

IGT recommends $1.0 million for a joint geoscience research effort with IGT, the School of Mines and Energy Development of the University of Alabama, and the University of West Virginia to determine, in a wide variety of coal seams, the correlations between geological properties such as coal type and rank, and amounts of recoverable methane.

DEVELOPMENT OF AN ADVANCED PROCESS FOR MILD GASIFICATION OF COAL

Although coal represents about 75% of the energy content of U.S. fossil fuel resources, less than 25% of the primary energy consumption is met with coal. A sound approach to a comprehensive national energy policy should include a broader use of our coal resources. Part of that strategy should include coal's use for applications other than simply as a fuel.

Most coal technology development in the U.S. has been oriented toward coal use in baseload electric power generation. One exception is the Department of Energy's program in mild gasification. This technology would be a significant benefit to the coal industry. It would allow coal to be used for new value-added products.

In mild gasification, coal is heated to moderate temperatures and pressures to produce gaseous fuels, a liquid hydrocarbon condensate and a solid char. The gaseous fuels are consumed to sustain the process and the condensate and char are used as raw materials for other processes, making them more valuable than if they were used solely as a fuel. The char may have uses in steel making, in water or waste water treatment, or as a "smokeless fuel" for either domestic or export use. The condensate can be used as a chemical feedstock and studies are underway to determine its use as a high energy density fuel for military applications.

Under DOE contract, The Institute of Gas Technology is heading a team of Peabody Holding Company, Bechtel National and Caterpillar to develop an advanced mild gasification process. IGT is constructing a 100 lb/hr process development unit using innovative gasifier technology. This technology will maximize the yield of the value-added co-products. The project has performed a market study which shows that there is good demand for the products that will be produced from the IGT process. Char utilization tests planned for the program will confirm the suitability of the char as a replacement for coke in the resurgent U.S. steel industry.

In order to determine economics and environmental and technical performance, as well as produce product for manufacturers to test, it is necessary to advance the IGT mild gasification process to the design, construction and operation of a 24 ton/day, mine-mouth process demonstration unit. Selected coals, representative of major U.S. coal resources, will be tested in the demonstration unit. The demonstration unit will also provide continuous operational data for process scale-up, as well as for construction and operation permits. The West Virginia University will provide specialized research support activities.

IGT recommends $0.4 million for the completion of the initial IGT mild gasification test program; and $3.0 million for initiating the engineering design of, and procurement of selected long-lead items for a cost shared 24 ton/day PDU based on the IGT concept.

TWO-STAGE FLUIDIZED-BED/CYCLONIC COMBUSTOR

Clean coal combustion processes are becoming more important in efforts to shift more of our energy demand to coal. These processes can produce two types of environmental impacts, emissions of gases into the atmosphere and production of solid wastes. Successful advanced coal combustion processes will have to address both of these environmental issues while maintaining high efficiencies and the lowest possible costs.

Commercial and developmental coal combustors can be grouped into two classes, those that operate under pressure and can be used in combined cycle power plants and those that operate at atmospheric pressure and are used in simple cycle operations.

There are two types of atmospheric pressure combustors, fluidized bed and slagging combustors.

Existing atmospheric pressure fluidized bed combustion technologies have two persistent ash problems that affect their efficiency. In order to prevent ash from sticking in the combustor, they must operate at relatively low temperatures. These low temperatures make heat transfer to the steam cycle less efficient. The combustion gases from atmospheric fluidized beds also carry large amounts of ash to the heat exchangers, depositing a layer of ash that lowers the efficiency of heat transfer. The combined effect of these two problems requires the use of larger, more costly equipment to recover the energy for steam and electricity production.

Slagging combustors operate at high temperatures. They have difficulty with simultaneous removal of both SO_x and NO_x while achieving acceptable slag removal.

To get around these concerns, DOE is developing pressurized fluidized bed combustion systems to improve the energy efficiency.

IGT has invented and patented an alternative, promising approach, an advanced two-stage coal combustor capable of either atmospheric or pressurized operation, which should minimize environmental impacts while maintaining high efficiencies. This approach combines IGT's unique technology and experience in fluidized beds and cyclonic combustion to simultaneously control SO_x and NO_x emissions and create an easily disposable solid residue.

The first stage of this combustor will consist of a fluidized bed in which sulfur is removed by limestone addition and NO_x formation is prevented by controlling temperature and the quantity of oxygen present. Use of IGT's patented sloping grid design allows the combustor to operate at higher temperatures than conventional fluidized beds and also provides for high ash discharge from the bottom of the fluidized bed. Over 98% of the ash and limestone residue will be removed in this first stage so that the gases leaving the first stage will contain very little solids.

The second stage, a cyclonic combustor, will combust the remaining gases and separate the solids prior to the heat exchangers, eliminating the efficiency loss caused by ash deposits on the heat exchangers. The following performance is predicted:

ash rejection in first stage	greater than 98%
NO_x emissions	less than 150 ppm
CO emissions	less than 100 ppm
sulfur reduction	greater than 90%

This combustor approach can be designed for either atmospheric or pressurized applications. The atmospheric pressure version will be used to replace individual utility burners for retrofit applications since it is expected to be smaller than existing fluidized bed combustors as a result of its reduced air requirements and relatively high combustion temperatures. The high pressure version will be able to be used in a combined cycle power plant to produce electricity at high efficiency with relatively simple equipment.

It is expected that the combustor will be able to use a wide range of feedstocks ranging from coal to coal wastes, peat, and refuse derived fuels.

Additional development is needed for integration of the two stages and optimization of the resulting two stage combustor at pressures ranging from atmospheric to 450 psi. This work can be performed using IGT's existing 6 million Btu/hr sloping grid fluidized bed facility.

IGT recommends $1.0 million for the development of an advanced two stage coal combustor based on IGT's sloping grid fluidized bed and cyclonic combustion technology, making use of existing PDU facilities.

EASTERN OIL SHALE

R&D PROGRAM RECOMMENDATIONS, FY90

Process Research

Eastern Oil Shale occurs in Alabama, Kentucky, Ohio, Indiana, Michigan, and Tennessee. The necessary mining infrastructure and water resources are available and the Eastern United States offers a close and ready market for liquid fuel products. Conventional thermal retorting technologies, however, cannot economically produce liquid fuels from eastern oil shale.

Tests have shown that retorting eastern oil shale in the presence of hydrogen dramatically increases the yield of oil compared to conventional thermal retorting. A multi-disciplinary team (Institute of Gas Technology, University of Alabama's Mineral Resources Institute, University of Pittsburgh, Illinois Institute of Technology, Ohio State University, Tennessee Technological University and the University of Michigan) has been advancing this concept under DOE contract by developing a new retorting technology known as pressurized fluidized bed hydroretorting (PFH).

Results to date are very encouraging. Applying the PFH process to Indiana New Albany shale produces twice the oil yield of conventional thermal retorting. The PFH process also achieves higher oil yields and uses less hydrogen than moving-bed hydroretorting, an alternative retorting approach for eastern oil shale. Therefore, the PFH process should be more economic than other eastern oil shale retorting processes.

To support the oil productivity increases of the PFH process, the project team is developing supplemental technologies including shale beneficiation, gas clean-up, shale oil upgrading and environmental impact mitigation.

Removal of solids from a high pressure retort such as that used in the PFH process is traditionally an inefficient and maintenance intensive operation. During the first year of the current project, IGT has developed a Restricted Pipe Discharge System (RPDS), which is more efficient and economical than conventional systems.

Another problem common to attempts to recover oil from any oil shale is its high inert mineral matter content. Removal of the mineral matter prior to retorting improves the efficiency and economics of the PFH process. Beneficiation research is being conducted by the Mineral Resources Institute of the University of Alabama and the University of Pittsburgh. This research shows that an advanced beneficiation process using column flotation increases oil yield potential in the retort to over 260% of that obtained when an equal quantity of non-beneficiated shale is used. PFH economics are further improved because of a 60% reduction of the sulfur content of the shale after beneficiation. In addition, column flotation achieves 20% better kerogen concentration and higher kerogen recovery in equipment one-eighth the size of that required by previous beneficiation techniques.

The PFH process requires use of hydrogen at elevated temperature and pressure. Conventionally, hydrogen is produced in a complex, five-step process starting with natural gas, which requires the gases to be repeatedly heated or cooled between process steps. This results in lower energy efficiencies and higher costs. IGT has developed and patented a high-temperature metal foil membrane process which should reduce the five gas processing steps to only one step. This process can be used at high temperature, retaining high thermal efficiency. It can also be used to recover unreacted hydrogen for reuse in the PFH process. This process needs further development and scale up for this application.

IGT has also developed another process for reducing hydrogen consumption, resulting in lower cost of finished products from oil shale. Hydrogen is used to remove sulfur and nitrogen from shale oil produced by any retorting process, adding a significant cost to producing saleable oil from oil shale. IGT has developed and successfully tested a novel catalyst to remove the sulfur and nitrogen using mixtures of methane and carbon dioxide instead of expensive hydrogen. This technology has been proven on upgrading coal derived liquids, but additional studies are needed to apply the technology to upgrading shale oil.

In order to determine the economics and environmental impact for a total eastern oil shale processing including mining, beneficiation, retorting and water and waste solids management, the PFH process must advance to design, construction and operation of a 4 ton/hour truck transportable process development unit. This unit would be moved to various shale sites to obtain operation data. It will also provide data for process scale-up and construction and operation permits.

IGT recommends $3.0 million for continued development of the PFH process including the use of the foil membrane in hydrogen production and use of carbon dioxide methane mixture in shale oil upgrading, and $1.5 million to initiate design and engineering of a 4 ton/hour transportable PFH process development unit.

Novel Concepts Research

At the end of FY86, three awards were made by DOE for research on novel concepts for oil shale processing. One of the projects was for research on an inert-gas, atmospheric-pressure fluidized-bed retort system being developed by the University of Kentucky Center for Applied Energy Research (CAER). The conceptual process, called KENTORT II, is a multiple fluidized bed process which improves oil yields from eastern oil shales over conventional technologies, produces valuable chemical by-products and decreases environmental problems associated with spent shale disposal. It incorporates three stages: pyrolysis, gasification and combustion.

Crude shale oil, the primary product, is produced in the pyrolysis zone. The gasification stage treats the shale for efficient and clean combustion, provides heat for pyrolysis by recycling the hot spent shale, and converts the spent shale into a more environmentally acceptable material. The combustion zone at the outlet of the gasification stage burns the unreacted carbon from the shale to provide the energy needed in the other stages. The results obtained so far in a 5 lb/hour integrated reactor system are very encouraging, showing oil yields up to about 150 percent of those expected from conventional thermal retorting at similar conditions.

Scale up of the KENTORT II process is necessary in order to better simulate the performance of a commercial system, produce larger quantities of shale oil and spent shale for testing, and determine engineering design parameters necessary for commercialization.

An additional novel concepts solicitation which does not require co-funding by the research teams should be issued in FY90.

IGT recommends $2.0 million for continuing novel concepts research, including efforts to extend the data base for the KENTORT II process.

Environmental Studies

Responsible technology development requires continuing environmental research to assure that the development of new technologies will not create adverse environmental impacts. Such studies should be continued during the development of the oil shale beneficiation and retorting and shale oil upgrading parts of this program.

The new technologies being developed under this program will produce spent shales which are physically and chemically different from those of previously studied conventional technologies. Obviously, environmental safety is essential for implementing an oil shale industry. Research in this area should be conducted simultaneously with process development so environmental solutions can be integrated into process design.

For the past five years, the University of Kentucky CAER has conducted research on the environmental characteristics of retorted eastern oil shale, with support from the Commonwealth of Kentucky and the DOE. The retorted oil shale was produced from a conventional technology originally designed for western U. S. oil shale. This effort has focused on the geotechnical, leaching and reclamation characteristics of the spent shale.

The work conducted at a field research station in Montgomery County, Kentucky, uses large concrete lysimeters to determine the elemental release or leaching characteristics of the materials. Shale materials are capable of forming acidic drainage and releasing environmentally sensitive elements in high concentrations, pointing out the need to further reduce the carbon and sulfur content of the shale to eliminate these hazards.

It is necessary to evaluate the disposal of spent oil shale with the characteristics of those from advanced technologies in large field and laboratory lysimeters. The lysimeter data will be incorporated with other information in a Systems Management Model to develop a flexible method for assessing the economic and environmental impact of various oil shale disposal methods.

The fully instrumented field research site operated by CAER will be used to study southern Indiana New Albany Formation oil shale that has been subjected to retorting and fluidized bed combustion. This material is similar in nature to that produced from an advanced eastern process such as KENTORT II and is available in sufficient quantity for meaningful field research.

The materials will be installed in the field lysimeters to duplicate a disposal pile. The chemistry of the leachates, generated under completely natural conditions, will be determined over several years and the physical changes of the shale will be documented. Additional lysimeter experiments will be conducted in the future at the University of Wyoming indoor lysimetry facility. This unique installation allows the environment to be completely controlled and the effect of extreme conditions, which cannot be expected in a short duration field study, will be assessed.

To ensure that the environmental studies are as useful as possible, a Systems Management Model approach will be utilized. The field data along with hydrologic, mineralogic, soil characterization and mine and retorting technology information will be integrated into a computerized model. This will allow the impact of chemical changes in the spent shale, along with variations in disposal practices and spent shale utilization options, to be easily assessed. The model and the fundamental data generated will also have applicability in the management of other energy related solid wastes.

IGT recommends $1.5 million to conduct environmental studies which would include University of Kentucky efforts to assess mitigation of the impacts of retorted, spent shale.

ENRICHED METHANE PRODUCTION FROM ANAEROBIC DIGESTION OF SOLID WASTE OR BIOMASS

Solid waste disposal is an increasing problem in the United States with landfills reaching capacity and alternatives such as incineration experiencing environmental problems. One alternative to incineration is biological conversion of municipal solid waste to methane, a clean burning fuel.

Conventional single-stage anaerobic digestion is a process long employed by industry and municipalities which uses microorganisms for pollution control and sludge stabilization. However, it produces a product gas that contains 60% methane and 40% carbon dioxide. The cost of removing the carbon dioxide to produce a pipeline quality gas (greater than 95% methane) from this mixture is prohibitive, ranging from $1.50 to $3.00 per million Btu.

Pressure swing absorption is a technique that is used to purify gas streams. It uses the difference in the solubility of a gas in a liquid at two different pressures to remove the unwanted gases. Integration of this technique with single stage digestion would eliminate the costly separation step. However, application of pressure swing absorption will increase the pH in the digester requiring additional chemicals to control the pH within the range needed by the microorganisms. This will represent an additional chemical cost of approximately $2.50 per million Btu of gas produced.

IGT has successfully tested carbon dioxide removal from the product of single stage anaerobic digestion of sewage sludge, under GRI/DOE contract. This is an important step towards producing pipeline quality methane gas from anaerobic digestion.

Use of two stage anaerobic digestion instead of single stage anaerobic digestion in combination with pressure swing absorption will eliminate the chemical cost required by single stage anaerobic digestion and also allow the use of smaller and more economic equipment because of the higher reaction rates in two stage anaerobic digestion.

Pressure swing two-stage anaerobic digestion promises to be the most economic means of producing a pipeline quality methane gas from solid waste or biomass since it eliminates both the need for carbon dioxide removal from methane and the use of chemicals for pH control.

IGT recommends $0.5 million to develop an integrated pressure-swing two-stage anaerobic digestion system based on the GRI concept using an existing PRU to economically produce pipeline quality methane from solid waste and biomass.

PRESSURIZED GASIFICATION OF REFUSE DERIVED FUELS

The disposal of municipal solid waste is becoming an increasingly crucial issue. Historically, solid wastes have been disposed of in landfills. However, in an attempt to reduce the volume of solid wastes and thereby increase the life of landfills, technologies have been developed and deployed for recycling and electric energy generation.

Waste-to-energy facilities primarily use mass-burn technologies, incinerating wastes to heat water to produce steam for generating electric power. Some waste-to-energy facilities manufacture refuse derived fuel (RDF) which is produced by removing the non-combustibles from municipal waste, producing a product to be used either alone as a fuel or as a supplement to coal in boilers.

Current mass-burn technologies still need improvement. Plants have suffered extended shutdowns for problems in fuel handling and ash removal. Serious questions have been raised regarding their emission of hazardous airborne pollutants. Consequently, there is still a need for alternatives to the mass-burn concept.

The use of RDF as a supplement to coal has suffered from unfavorable economics. Because of the high ash content of RDF, using it with coal results in increased boiler maintenance, eliminating the incentive for a coal boiler operator to use RDF.

IGT has developed RENUGAS, a pressurized, fluidized-bed process for the gasification of biofuels which can be applied to the gasification of RDF. Using RENUGAS to gasify RDF as part of a combined cycle power plant will allow the use of municipal solid waste to produce electricity in a highly efficient, environmentally sound manner.

The use of RENUGAS allows the conversion of RDF to electricity without the release of harmful emissions or the creation of dioxins. Power generation efficiencies up to 45% are expected from RENUGAS RDF gasification compared to efficiencies up to 33% from mass-burn steam cycles. This efficiency increase will result in a 25% decrease in the amount of CO_2 released for the same amount of electricity produced.

The RENUGAS process can also convert RDF into a synthetic gas that can be used to create methanol, which can then be used to generate electricity, as a transportation fuel, or as a chemical intermediate.

Another problem with mass burn facilities is that they are only economic at large sizes, limiting their usefulness to large metropolitan areas or regional facilities. A RENUGAS combined cycle power plant will be available in a wider range of sizes. This would make the technology and its environmental benefits available to a broader range of users.

IGT recommends $1.5 million to apply the RENUGAS technology and IGT's existing process research unit to the gasification of RDF, directed toward both electric power and methanol production.

CARBON DIOXIDE REMOVAL USING HYDROCARBON PRODUCING ALGAE

The trend toward global warming, known as the greenhouse effect, has been attributed in part to the increasing concentration of carbon dioxide in the atmosphere. Carbon dioxide is released into the atmosphere during the combustion of all fossil fuels.

Despite growing concern about the environmental effects of carbon dioxide release, we cannot readily abandon the use of fossil fuels. The economies of both developed and developing nations are dependent on fossil fuel use for energy needs ranging from transportation, electricity generation, and heating to manufacturing. Fossil fuels are also an essential part of the world's energy resources. Since fossil fuels are likely to be used for many years, means to either remove the carbon dioxide from, or prevent its escape into, the atmosphere are being considered.

Photosynthesis is a natural process for recycling and fixing carbon dioxide. One U.S. electric utility is attempting to balance the CO_2 produced from one of its power plants by agreeing to plant 52 million trees in Guatemala. This can only be considered as a slow, long term remedy and will require very large areas. The company estimates that two square miles of forest are required to mitigate carbon dioxide emissions from one megawatt of electrical capacity.

Another approach is to use hydrocarbon-producing algae to remove and fix carbon dioxide and obtain a storable and reusable energy source. Algae are an order of magnitude more efficient users of land area for carbon dioxide removal than are forests or crop plants. They also produce hydrocarbons that can be collected and converted to liquid fuel. The algae can be harvested and used for a variety of purposes. Other researchers are testing the use of large shallow ponds (up to 50 acres and 6 inches deep) for algae growth. This will require large areas of flattened land surfaces resulting in high site acquisition and preparation costs. Recovery of the algae from large ponds will also be costly. In the shallow pond concept, the carbon dioxide is bubbled into the pond and removed by the growing algae. During darkness, the algae will be less efficient, requiring the reduction of power plant output, the release of carbon dioxide into the atmosphere, or a fresh approach to begin to control carbon dioxide.

IGT recommends that carbon dioxide from a fixed point source such as a power plant can be scrubbed to produce carbonate or bicarbonate solutions, a more readily usable and efficient carbon dioxide source for the algae. This solution can be used to feed a thin film of algae in an attached film reactor (AFR). In an AFR, a thin film of algae, approximately 1 millimeter thick, will be attached to an inclined surface and be sprayed with the carbonate or bicarbonate solution during daylight hours. Mature algae will be washed down the incline, transporting the algae and the hydrocarbons they produce for collection, separation and use. The combination of using carbonate or bicarbonate solutions and the ATR technology should reduce the land requirement by an order of magnitude compared to the shallow pond approach.

The carbonate or bicarbonate solution can be collected whenever a power plant is in operation, sprayed directly on the AFR during the day and held in storage tanks at night. Hydrocarbons produced by the algae would be collected for use as a fuel.

IGT recommends $0.5 million to produce a more active algae and evaluate the attached film reactor concept using carbonate and bicarbonate solutions as a means of reducing carbon dioxide released to the atmosphere from point sources.

Testimony of Charles J. Mankin, Chairman

ACTION COUNCIL FOR COORDINATED OIL AND GAS RESEARCH AND DEVELOPMENT (ACCORD)

Before the House Science, Space and Technology Committee
Subcommittee on Energy Research & Development
Honorable Marilyn Lloyd, Chairman
February 22, 1989

Madam Chairman, it is with great concern that I appear before this subcommittee this morning to discuss the FY90 DOE budget request for fossil energy research and development. The Action Council for Coordinated Oil and Gas Research and Development was organized to endorse the recommendations of the Energy Research Advisory Board's report "Geoscience Research for Energy Security." ACCORD is comprised of more than 80 organizations of government officials, national, state, and regional associations, universities and research organizations, and petroleum experts in private life.

America is now at an important crossroads. In 1989, Congress and the new Administration, in cooperation with the states and America's oil and gas producers, must make a fundamental choice about America's energy future: Effective abandonment of America's remaining oil and gas resource base in favor of imported fuels from the Persian Gulf, OR research and development to allow economic production of as much as 100 billion barrels of America's 325 billion barrel remaining oil resource. If we act forthrightly and cooperatively through an integrated policy of incentives, research, and technology development, we can sustain and improve our domestic production until economic and environmentally sound alternatives come to the forefront.

Low prices and aging reservoirs are causing the nation's producing oil and natural gas wells to be abandoned at an alarming and accelerating rate. That's a problem because plugging and abandoning the wells bars future economic access to the reservoirs thus permanently abandoning the remaining oil and gas resource. Meanwhile, America's dependence on foreign oil and refined products has exceeded 45 percent and approaches 50 percent.

As much as 100 billion barrels of this remaining oil resource and an appreciable amount of our gas resource could be recoverable at reasonable prices through improved geoscientific understanding of the resource base, advanced extraction technologies, and adequate economic conditions and incentives to promote their application. But if these geoscientific, technological, and economic improvements are not achieved soon, our opportunity to produce this remaining resource in known fields may be lost forever.

America is going out of the oil and gas recovery business. While they have done everything possible within the bounds of rational business practice, the majors are shifting their exploration budgets increasingly abroad, importing ever larger quantities of cheap foreign oil, and making the bulk of their domestic profits in downstream refining operations. They have cut their U.S. exploration and production research budgets sharply. The non-integrated, independent domestic oil and gas operators lack the revenues, financial backing, and technological sophistication to perform the research necessary to apply the needed new technologies to produce America's remaining oil and gas resources.

If we hold to our present course, the cost of imported crude and refined products in constant dollars will rise from $34 billion in 1987 to $120 billion by 2000. Wouldn't those dollars be much more effective if cycled through the domestic economy rather than those of foreign producers? Both DOE and the Commerce Department have concluded that this growing dependence on foreign oil represent a real threat to U.S. national security, leaving America -- and her allies -- extremely vulnerable to economically or politically motivated supply disruptions or world oil price escalations. It is time to change course.

Prioritized, integrated, coordinated, problem-oriented, interdisciplinary oil and gas research holds great promise. But to make it happen the nation, at the federal and state level, must choose an integrated and cooperative policy of incentives and R&D.

ERAB called for DOE to consolidate 17 programs of hydrocarbon geoscience research existing without coordination under 3 different assistant secretaries into one single office reporting to the Secretary. But DOE responded by adding two new bureaucratic offices, numbers 18 and 19: the Office of Geoscience Research (OGR), and the Hydrocarbon Geoscience Research Coordinating Committee (HGRCC). While we are pleased that -- after a prolonged search -- DOE has appointed a highly qualified Director for OGR and a strong staff, we are concerned that the office's charter is not sufficient to address ERAB's recommendations and that it has no budget of its own. We fear that the HGRCC promises to serve only as the battleground for bureaucratic turf battles within DOE and between DOE and other agencies -- without regard for getting on to solving our real national oil and gas problems. Madam Chairman, we submit that this critical research program deserves better.

Improved geoscientific understanding of reservoir heterogeneities and basin-specific conditions and development of advanced secondary and tertiary extraction technologies could allow some 30 - 50 billion barrels of unrecovered mobile oil in known reservoirs to be recovered. In addition, such advances could enable production of some 35 to 50 billion barrels of immobile oil, oil that is trapped in the rock by viscous and capillary forces. Combined, these 60 - 100 billion barrels of oil are more than enough to restore and sustain current production levels for the foreseeable future. And in that time period, other novel extraction techniques could result in even more substantial recoveries.

According to Gas Research Institute, some 583 trillion cubic feet of domestic gas resources could be economically recovered at prices below $ 3 per Mcf. As with oil, there is a significant potential for infill drilling to drain known gas reservoirs more thoroughly, encounter undrained "lenses" of gas, and more fully develop deep gas resources. Unconventional gas resources, including tight gas formations, methane gas from coalbeds, and Devonian shale gas are also significant and substantial resource targets. Collectively, the benefits of improved geoscientific understanding and characterization of the resource and advanced extraction techniques could triple current proved gas reserves.

A NATIONAL OIL AND GAS POLICY: To access these promising but threatened resources, we must act quickly to achieve four goals:

- Geoscientific understanding of the reservoirs must be improved.
- Advanced oil and gas extraction technologies must be developed.
- Economic access to known reservoirs through existing wells must be maintained.
- Economic conditions must prevail to permit applications of the improved technologies.

The choice is clear and the time is urgent: to develop America's remaining oil and gas resource base necessitates an integrated, strategic national oil and gas policy that includes four major integrated components:

R&D to sustain existing wells, improve geoscientific description of reservoir heterogeneities, and advance recovery technologies is the foundation upon which the other components of the policy must rest. Without these technologies, none of the other policies can be fully effective.

State and/or federal tax and other economic incentives are essential to encourage extended production life and application of advanced oil and gas technologies. Careful analysis must define the form and function of these incentives to prolong the life of existing wells and stimulate new reserves, while avoiding unacceptably high costs to public treasuries.

Cooperative environmental protection efforts are needed between, DOE, EPA, the states, and oil and gas operators that allow for both effective surface and subsurface protection and economic and competitive oil and gas production. We urge early and aggressive transition to natural gas fuels in the transportation, home heating, utility, and industrial sectors, where appropriate.

Complete and augment the U.S. strategic response to supply disruptions by filling the Strategic Petroleum Reserve (SPR) to its planned level of 750 million barrels, or more, retaining the Naval Petroleum Reserves as additional strategic reservoirs, that could be critical in the event of an oil or gas supply disruption.

A DOE OFFICE OF OIL AND GAS POLICY AND RESEARCH: The Department of Energy should create an Office of Oil and Gas, with its own assistant secretary, to consolidate and manage all current and future DOE oil and gas related research and policy analysis. The office would be comprised of the oil and gas personnel of the Office of Fossil Energy, and appropriate personnel from the Office of Policy Planning and Analysis, the Office of Energy Research, and the Office of Conservation and Renewable Energy. It would integrate and focus the oil and gas related programs according to a prioritized, problem-oriented, strategic plan, consistent with a national energy policy. The Office of Fossil Energy -- excluding oil and gas programs -- would be renamed the Office of Coal with its own Assistant Secretary, and would retain all of its current jurisdiction over the coal research, clean coal technology, MHD, and other non-oil and gas related programs. Current Congressional authorization and appropriation committees and subcommittees would retain their present roles.

Proposed Research Plan

The DOE Office of Oil and Gas, as envisioned, should implement an inter-disciplinary program of research, integrated by a quantitative and analytically based strategic plan. Research would provide the understanding, tools, and technologies needed for successes in the applied research areas of field/reservoir frameworks, reservoir characterization, reservoir performance prediction, advanced extraction technology, stimulation and completion, and resource assessment and technology transfer. These interdisciplinary efforts would focus on solving the problems that limit the economic producibility of specific resources in the most promising basins and formations (as defined in the strategic analysis) before these resources are abandoned. Complementing these interdisciplinary efforts would be additional research in the respective disciplines focused on advancing the scientific basis underlying the more applied, problem-oriented efforts.

By and large, the institutions currently performing the research under the current, diffuse and uncoordinated plan -- universities, the National Labs, federal and state research agencies and contract researchers -- would be the same under the integrated, focused program, because these institutions contain the requisite expertise and facilities. But their efforts would be focused on solving truly pressing problems of national strategic value.

APPROPRIATE SUFFICIENT FUNDS TO GET THE JOB DONE: In order to avoid the imminent abandonment of a substantial portion of the remaining domestic oil resource base, and to preserve the option of improving domestic oil and gas production and sustaining those levels, the Department of Energy and Congress should consolidate and accelerate funding for the oil and gas geoscience and extraction research programs in FY90. The leadership shown by Congress on the clean coal technology program is indeed commendable. We submit that a similar commitment is essential to meet America's urgent needs in oil and gas R&D. We must look at the national interest. America simply can not afford another year of dismantling and diffusion of her national oil and gas research capabilities.

Therefore, we urge this Congress and this new Administration most strongly to authorize and appropriate a consolidated FY90 oil and gas geoscience and extraction research and policy budget. At the current FY89 levels, that's about $102 million, including $49.9 million from the Interior and Related Agencies Appropriations, and $ 52.7 million from Energy and Water. To this, we recommend adding a total of $50 million, consistent with the ERAB recommendations of two years ago.

- For policy and strategic planning and analysis, allocate $1.5 million to oil and gas policy specifically.
- From the Office of Energy Research, Basic Energy Sciences program, incorporate the Engineering and Geosciences programs at the FY89 baseline level of approximately $33 million.
- From the Office of Conservation and Renewable Energy, include the Geothermal and Geopressured research program at the FY89 baseline level of $19 million.

Thus, the research program funds under the Energy and Water Appropriation would total $53.5 million, approximately the same as the FY89 baseline.

- From the Office of Fossil Energy Oil and Gas Research Programs, include the Advanced Extraction and Process Technology Program at a level of $4 million dollars, and the enhanced oil recovery and tar sands programs at a combined level of $24 million.
- Include the Oil Shale program budget at $10 million.
- Include the unconventional gas research program of the Office of Fossil Energy at $12 million.

Thus the levels to be appropriated from existing programs under the Interior Appropriation Bill would total $50 million, or roughly the FY89 base level.

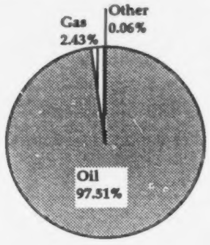
Finally, Madam Chairman, we recommend a series of new integrated interdisciplinary oil and gas initiatives, in accordance with the strategic research plan, which relates these initiatives with the existing programs. Congress should authorize and appropriate $50 million dollars for this purpose in FY90 and rising to a maximum of $100 million as the budget permits over the next two years. This proposal recognizes the fiscal responsibilities and constraints of the Congress and the Administration. Much of the funding for this essential research can be made available by consolidating the programs as described above. All of these programs were identified as oil and gas geoscience related by ERAB. Where ERAB had recommended funding levels of $134.2 million for FY87 and $184.2 million by FY90, Congress appropriated $102.6 in FY89. Yet DOE requested only $78.1 for FY90. Within the programs under the Interior and Related Agencies appropriation, DOE's request for FY90 of $28.6 million represents fully a 43% decrease below the current year.

The program recommended by ACCORD and its members totals $152 million -- some $32 million less than ERAB conservatively estimated as necessary to get the job done in FY90.

A commitment to these implementation steps, and to the modest budget we've recommended, will begin, finally, to restore a balance between national oil and gas research priorities and the national energy requirements of the nation for now and well into the future. Such a program and a budget will provide the time we so desperately need to develop alternative fuels to enhance national security, promote wise economic growth, and keep America internationally competitive as we move into the next century.

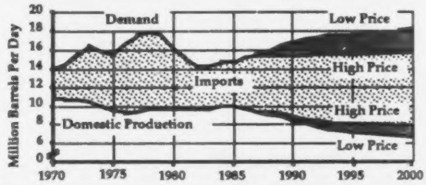
I urge your thoughtful consideration and adoption of these proposals and I thank you for your time this morning. I would be happy to answer any questions you or the members of the subcommittee may have.

Figure 1: Demand for Energy in Transportation Sector



Source: EIA, 1988

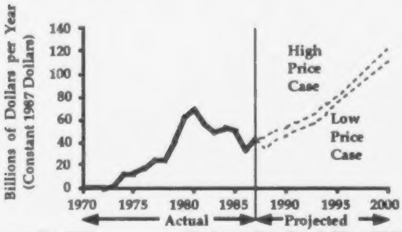
Figure 2: U.S. Dependence on Imported Crude Oil and Refined Products



Source: EIA, 1988

EIA Lower Price Trend: $13 to $25/bbl
EIA Upper Price Trend: $18 to $40/bbl

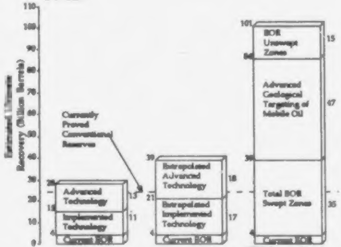
Figure 3: Cost of Imported Oil and Refined Products



Source: EIA, 1988

EIA Lower Price Trend: $13 to $25/bbl
EIA Upper Price Trend: $18 to $40/bbl

Figure 4: Estimated Additional Oil Recovery from Known Fields



Sources: NPC, 1984; BEG

Table 1: Recommendations for Consolidated FY90 DOE Oil and Gas Research & Development ($Millions)

	UNCONSOLIDATED				CONSOLIDATED
CONSOLIDATE UNDER NEW DOE OFFICE OF OIL & GAS:	FY87 (ERAB Base)	FY88 Actual	FY89 Actual	DOE/Admin FY90Request	ACCORD FY90 Recomm.
Energy & Water Appropriation					
Office of Policy Planning Analysis					
Oil & Gas Policy Analysis	*	*	*	*	1.5
Office of Energy Research (BES)					
Engineering	14.1	14.7	15.3	15.8	15.3
Geosciences	15.4	16.3	17.8	18.3	17.8
Office of Conservation & Renewables					
Geothermal/Geopressured R&D	20.8	20.7	19.6	15.4	19.6
Subtotal, ENERGY & WATER	50.2	51.7	52.7	49.5	54.2
Interior Appropriation					
Office of Fossil Energy					
Advanced Extraction & Process Tech	3.8	3.5	4.4	4.6	4.4
Enhanced Oil Recovery/Tar Sands	11.2	16.6	23.6	18.2	23.8
Oil Shale	11.0	9.5	10.5	1.7	10.5
Unconventional Gas Research	8.0	10.5	11.4	4.1	11.4
Subtotal, INTERIOR	34.0	40.0	49.9	28.6	49.9
TOTAL CONSOLIDATED PROGRAMS	84.2	91.7	102.6	78.1	104.1
ADD NEW INTEGRATED OIL & GAS INTERDISCIPLINARY INITIATIVES	—	—	—	—	50.0
TOTAL INTEGRATED PROGRAM	84.2	91.7	102.6	78.1	154.1
ERAB Recommended Level		134.2	159.2	184.2	184.2
Difference		(42.5)	(56.6)	(106.1)	(30.1)

* Previously included in other budgets; could be reduction from the former budget lines.
Note: Totals may not add due to independent rounding.

COMBUSTION ENGINEERING

Timothy R. Osborn
Manager
Government Affairs

February 21, 1989

The Honorable Marilyn Lloyd
Chairman
Subcommittee on Energy
Research and Development
U.S. House of Representatives
Committee on Science, Space, and Technology
2321 Rayburn HOB
Washington, D.C. 20515-6301

Dear Chairman Lloyd:

We would like to submit the enclosed testimony for the Subcommittee's consideration in making funds available for the Department of Energy's (DOE) support of fuel cell development programs. As a leading manufacturer of power generation systems, Combustion Engineering is directly involved in the development of molten carbonate and solid oxide fuel cell technologies. We share the views of the fuel cell industry that DOE's fiscal year 1990 budget proposal will not provide the needed resources to maintain an effective program of fuel cell development.

Combustion Engineering's testimony is supportive of the statement that Mr. Frank Schora, President of M-C Power, will make before the Subcommittee on Wednesday, February 22. Should you have any questions concerning our comments, we will be happy to respond.

Your consideration of our testimony and views is appreciated.

Sincerely,

TRO/yj
Enclosure

Combustion Engineering, Inc.
1101 Fifteenth Street, N.W.
Suite 500
Washington, D.C. 20005
(202) 429-9180

TESTIMONY OF COMBUSTION ENGINEERING, INC. TO THE U.S. HOUSE OF REPRESENTATIVES SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

February 22, 1989

Combustion Engineering, Inc. (C-E) would like to testify today in support of molten carbonate and solid oxide technologies development. Department of Energy support for these programs is vital to commercialization of said fuel cells.

C-E is a worldwide multi-national corporation, supplying power generating systems and services to utilities, process industries, municipal, and institutional markets. Equipment of C-E design represents over forty percent (40%) of the western world's fossil fired utility boilers. C-E has also provided fifteen operating pressurized water reactors (PWR's) to U.S. utilities. Two additional PWR's are under construction in Korea. In addition to servicing our power generating plants, C-E designs and constructs municipal waste to energy units, provides the process industry with petrochemical plant designs/erection, designs and builds process (computerized) control software with related systems, and provides pollution abatement/environmental clean-up support.

C-E has concluded that environmentally clean, highly efficient, fuel flexible, modular energy systems with short construction times are necessary to serve future power generation market needs. Fuel cells, specifically the molten carbonate and solid oxide devices and related systems, can meet these future demands.

C-E considers that the molten carbonate fuel cell (MCFC) will provide dispersed site cogeneration capabilities, i.e., electricity as well as steam heat, to the commercial and light industrial markets as soon as the mid nineties, using natural gas fuel. Later, 50 MWe plus coal gas fueled MCFC's can be effectively used by utilities for load levelling and repowering of older urban sited pulverized coal fired boilers. Substantial environmental gains can be achieved - i.e., essentially no SOX releases, and greater than eighty percent (80%) reduction in NOX emissions.

The monolithic solid oxide fuel cell (MSOFC) is viewed as serving the smaller commercial and residential market needs, (<250 KWe), with a highly efficient clean natural gas fueled energy source early in the 21st century.

Focusing on MCFC's, C-E has become a stockholder in M-C Power, with the sole objective of developing and commercializing MCFC power generating systems during the next six to eight years. Under DOE subcontract with M-C Power, C-E is to provide systems engineering and controls design plus fabrication, power conditioning, and environmental guidance. Moreover, under a separate agreement with M-C Power, C-E will market, sell, and service MCFC systems.

For MSOFC development, C-E has teamed with Argonne National Laboratory (ANL) and Allied Signal Aerospace AiResearch Division (ASA). C-E has purchased exclusive world wide fabrication and selling rights to this ANL unique invention. C-E will design, fabricate and sell MSOFC systems, ASA will fabricate the monolithic stacks, and ANL will continue with fundamental research aimed at materials improvement and fabrication process enhancement.

C-E considers the FY'90 DOE budget to be inadequate for fuel cell development.

C-E urges that an aggressive program be adopted to accelerate MCFC systems development. As competition is paramount to market entry innovativeness, C-E supports funding all three contractors involved in MCFC development at $8M each, (total $24M) for FY'90. For FY'91 and FY'92 C-E recommends an accelerated effort at $10M and $12M respectively for the M-C Power team. Insofar as issuance of a new MCFC PRDA by mid '89, the objective should be continued development of fuel cell stacks and systems by all three contractors. Downselection should be deferred until FY'93.

For monolithic solid oxide fuel cells, C-E urges that the Subcommittee provide an additional $2M in FY'90 and $3M in each of the two succeeding out years, focused on MSOFC process development, stack fabrication, and testing.

C-E thanks the Subcommittee for the opportunity to submit this testimony in support of fuel cell development and commercialization.

Southern Company Services, Inc.
Post Office Box 2625
Birmingham, Alabama 35202
Telephone 205 870-6011

Southern Company Services
the southern electric system

February 17, 1989

The Honorable Marilyn Lloyd, Chairman
Subcommittee on Energy Research and Development
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, D.C. 20515

Dear Congresswoman Lloyd:

Attached is written Testimony that Southern Company Services, Inc., requests be included in the record of the February 22, 1989, hearings before the Energy Research and Development Subcommittee of the House Committee on Science, Space, and Technology. This Testimony requests Congressional support for continued operation of the Wilsonville Advanced Coal Liquefaction Research and Development Facility in Wilsonville, Alabama. The Wilsonville pilot plant is the only facility in the United States that can conduct engineering-scale research on direct coal liquefaction processes. With increasing dependence on imported oil, the United States is becoming more vulnerable to another oil crisis and hence, the research being performed at Wilsonville is becoming more important.

The economics of direct liquefaction continues to improve. The latest estimated cost for producing coal-derivced fuels is $40 per barrel, down from over $90 per barrel in the early 1980's. If direct liquefaction technology can be commercialized, it will reduce U.S. dependence on imported oil, reduce the possibility of future energy crises, and reduce the U.S. balance of trade deficit.

If you have any questions, or need additional information about this testimony, please call me at (205)870-6326.

Sincerely,

Gary A. Styles
Manager,
Advanced Fuel Utilization

:0013A

Attachment

cc: Members of Subcommittee on Energy Research
and Development

THE FY 1990 FOSSIL ENERGY BUDGET PROPOSAL

Testimony of

Gary A. Styles
Manager, Advanced Fuel Utilization
Southern Company Services, Inc.
to the
Committee on Science, Space, and Technology
Subcommittee on Energy Research and Development
U.S. House of Representatives

February 22, 1989

Chairman and Members of the Committee:

Summary

The purpose of this testimony is to request funding of $8.5 million for FY'90 in the Department of Energy's Fossil Energy Budget for the continued operation of the Wilsonville Advanced Coal Liquefaction Research and Development Facility. The continuation of this project is of vital importance to the energy security of the United States because we continue to be vulnerable to another oil crisis through either high prices or shortages. Direct coal liquefaction can cap the price the United States pays for imported oil and can also help reduce the trade deficit. The coal liquefaction research program at Wilsonville has resulted in significant improvements in the economics of coal-derived liquids - for example, a 57 percent decrease in $93 per barrel cost in 1983 to the present. However, more work needs to be completed before coal-derived liquids can economically compete with petroleum. The objective of the Wilsonville research program is to reduce the cost of coal-derived liquids by 20 percent from the present cost of about $40 per barrel to $32 per barrel, an oil price that can be reached in the next five years even without a crisis. Over the next year, the Wilsonville project plans to focus its research on obtaining higher yields from bituminous coals, on testing less expensive coals, and on improving catalysts and process configurations. If these improvements can be made, it may be possible to have this technology economically ready before another oil crisis occurs.

If the Wilsonville program is terminated, the government will have to spend $30 to $50 million during the next oil crisis to build and operate a similar facility to complete the development of the technology. More important, it will take at least five years to re-learn the operating and maintenance techniques that are presently well understood at Wilsonville.

Introduction

Due to declining domestic petroleum reserves and production, increased domestic oil consumption, and increased dependence on imported oil, the United States is very vulnerable to another oil crisis. Presently, oil is the major source of transportation sector fuels and there are no available near-term alternatives. With continued research, direct coal liquefaction can potentially provide an alternative fuel source in as little as 5 to 10 years.

Recent developments have shown that as much as 78 percent of low-ash, high-carbon eastern bituminous coals can be converted into distillate fuels. In addition, revised estimates of the economics of direct coal liquefaction technologies show that the cost of producing coal-derived liquids has been reduced from $93 per barrel in 1983 to $40 per barrel in 1988 through improvements in technology and plant design. If commercialized, coal-derived liquid fuels can reduce U.S. dependence on imported oil and can also reduce the U.S. balance of payments deficit.

Wilsonville is the largest operating coal liquefaction pilot plant in the United States but it is also the smallest size at which steady-state evaluations of advanced coal liquefaction technology can be conducted. The facility, which was built without federal funds, cost over $25 million to construct. In addition, an important resource at Wilsonville is a staff of 95 experienced engineers, chemists, operators, and maintenance personnel with an average of over 10 years experience in coal liquefaction research. Wilsonville has the reputation of being one of the best coal liquefaction research projects in the world. Japan, the United Kingdom, Canada, Australia, and the People's Republic of China all continue to support development of direct coal liquefaction as a method of reducing dependence on imported oil. If the Wilsonville program is terminated, the United States will lose its leadership in this technology which it needs in order to be ready for the next oil crisis.

U.S. Dependence on Imported Oil

Less than three years ago, 27 percent of the U.S. oil supply was imported. In 1988, the foreign share was about 47 percent and is expected to rise to 50 to 70 percent in the 1990's.[1,3] In 1987, the cost for imported oil was $47 billion. By the year 2000, the import oil bill is estimated to be $200 billion. Large oil imports not only leave the United States vulnerable to oil embargoes and energy crises, they also adversely affect the U.S. trade deficit and the ability to pay for imports.[4] In 1988, imported oil accounted for $38 billion (through November), or over 30 percent of the total U.S. trade deficit.

The increase in U.S. dependence on imported oil is caused by both increased oil consumption due to lower oil prices and by declining oil production due to decreased exploration. Oil consumption was five percent higher in mid-1987 than it was for the corresponding period in 1985. Drilling activity in the United States reached a post-World War II low during 1986.[1] In 1981, as many as 4,500 drilling rigs were active. For the period 1982-1985, an average of 2,400 rigs was active. This level of activity was just sufficient to maintain a constant level of reserves. In the last half of 1986 and first half of 1987, only 800 rigs were active. While the full effect of this drop on production has yet to be felt, crude oil production has already dropped from 9.1 million barrels per day in February, 1986, to 8.3 million barrels per day in January, 1987, and averaged only 8.1 million barrels per day for 1988.[4]

The major reason for this drop in drilling activity and production is low oil prices. According to Robert L. Hirsch, Vice President for ARCO Oil and Gas Company, "Because people are generally happy with lower energy prices, and because the country tends to be short-term oriented, there appears to be a low probability of action before the problem becomes severe."[1]

The current volatility in oil prices has adversely affected petroleum industry planning. The lag between planning and new production is on the order of 5 to 10 years. If another energy crisis occurs, it will take 5 to 10 years before the U.S. economy can adjust as evidenced during the crises of the 1970's.

The principal importance of oil is that it is presently the primary source of fuel for motor vehicles and aircraft. Moreover, oil represents one-fourth of the total U.S. energy use and is the only major energy resource in which the United States produces less than it consumes. While natural gas or coal can be used to replace oil for some industrial applications, most conversions to natural gas have already been made. Unlimited, low-cost natural gas cannot be relied upon to reduce U.S. dependence on imported oil. The high rate of drilling for natural gas between 1980 and 1986, compared to the 1970's, did not increase reserves because natural gas was being consumed at the rate at which it was being discovered. In the first half of 1987, drilling for natural gas was 33 percent below the same period in 1986. The impact of this reduced drilling activity has not yet been felt but will ultimately result in decreased supply and increased cost for natural gas.[1,4]

Due to low oil and gas prices and tighter environmental regulations, many energy consumers are switching back to oil or natural gas. Between 1990 and 2000, it is estimated that 89,000 megawatts of electric power generating capacity will be added in the United States.[7] Of this total, 46,700 megawatts will be combustion turbines or combined cycle capacity which will require premium liquid or gaseous fuels. This trend will increase U.S. dependence on imported oil.

While the United States is deficient in oil supply and production capability, it does have abundant resources of coal and oil shale that can be used to eliminate dependence on imported oil and reduce the balance of payments deficit. Coal accounts for 80 percent of the recoverable fossil fuel reserves in the U.S. but supplies on 23 percent of the energy consumed.[6] It is estimated that 625 billion barrels of liquid fuels can be produced from coal and oil shale, which far exceeds Saudi Arabia's present 166 billion barrels of reserves.[2]

Most of these arguments have been made before and were a primary justification for the synthetic fuel development programs of the late 1970's and early 1980's. Results from those programs showed that liquid fuels would cost as much as $93 per barrel. For a number of reasons, the present Administration eliminated support for further development of clean liquid fuels. In the face of this indifference, Congress has continued to support clean liquid fuel research at minimum levels throughout the 1980's through basic laboratory research and at pilot scale facilities such as the Wilsonville Advanced Coal Liquefaction R&D Facility. As a result, coal liquefaction technology has continued to improve. Amoco Corporation recently revised the estimated cost of coal-derived liquid fuels. The revised cost estimate was based on improvements made at the Wilsonville Advanced Coal

Liquefaction R&D Facility, on design improvements, and on changes in U.S. economic factors. Amoco's latest estimate shows that the cost, based on these improvements, of coal-derived liquids is down to $40 per barrel, a 57 percent decrease since 1983.[5]

Wilsonville Accomplishments

Some significant recent accomplishments of the Wilsonville facility are:

- From 1982 to 1985, integrated two-stage liquefaction (ITSL) was developed and demonstrated at steady-state conditions. Using an integrated system of a thermal reactor for the first stage and an ebullated-bed catalytic reactor as the second stage, 60 percent of typical eastern bituminous coal was converted to distillate fuel. This was a significant increase over previous systems, which typically converted 50 percent or less into distillate fuel. It was this breakthrough which caused Amoco to re-evaluate its cost estimate for coal derived liquids.
- In 1984, over 50 percent distillate was produced from low-rank western subbituminous coal by using an inexpensive disposable catalyst in the ITSL process.
- In 1985, the objective of the Wilsonville program was changed to emphasize research into fuels that can be used in the transportation sector rather than clean boiler fuels as in the early 1980's.
- In 1986, a mathematical model was completed which simulates the Wilsonville ITSL process.
- In 1987, staff was reduced by 15 percent and operating cost were reduced by 7 percent due to reduced funding. The quality of the research program was only minimally affected. The project is currently at minimum staffing for an effective research program.
- In 1987, a second ebullated-bed catalytic reactor was added and research into close-coupled two-stage liquefaction began. In late 1987 and early 1988, 78 percent distillate yield was produced from low-ash, high-carbon Appalachian coal.

Wilsonville Goals

The goal of continued coal liquefaction research at Wilsonville over the next two years is to reduce the cost of coal-derived liquids from the current $40 per barrel by another 20 percent to $32 per barrel. It is not unreasonable to expect oil prices to reach $32 per barrel in the next five years under non-crisis conditions. If coal-derived fuels can be produced for $32 per barrel, there is a reasonable possibility of commercializing direct liquefaction before the next oil crisis occurs. If coal liquefaction can be commercialized under non-crisis conditions, the price the United States has to pay for imported oil will be effectively capped. Commercialization can also help reduce the trade deficit by replacing imported oil with fuels produced from the domestic coal reserves. Research over the next years will focus on:

- low-ash, high-carbon eastern bituminous coals which may increase the quantity of distillate yields.
- improved catalysts which may lower capital and operating cost, increase distillate yields, and improve product quality.
- improved process configurations which may lower capital and operating costs.

Wilsonville Capabilities and Private Sector Cost Sharing

The Wilsonville pilot plant has several unique features that make it well suited for continued coal liquefaction research. These include:

- A staff of 95 experienced engineers, chemists, operators, and maintenance personnel with an average of over 10 years experience in synthetic fuel research.
- Proven capital equipment valued at over $25 million that was purchased with funds from non-government sources [Electric Power Research Institute (EPRI), Southern Company Services (SCS), and Kerr-McGee Corporation]. The Wilsonville pilot plant includes two ebullated-bed catalytic reactors, an efficient Kerr-McGee Critical Solvent Deashing unit for ash removal, and all necessary support equipment such as waste water treatment and data acquisition systems.
- A non-proprietary research program that is designed to disseminate as much information as possible to industry.

Cost sharing for the Wilsonville project is provided by EPRI, Amoco Corporation, and SCS. Through 1988, 38 percent of the total project cost of $121.3 million has been provided by the above mentioned co-sponsors. All capital costs are paid by EPRI. In 1989 and 1990, we estimate that a minimum of $750,000 per year will be provided by co-sponsors. SCS is actively seeking additional private sector co-sponsors. In addition to cost sharing, SCS has implemented changes in the project organization that will save DOE $600,000 to $700,000 per year beginning FY'89.

References

1. "Impending United States Energy Crisis," Robert L. Hirsch, Science, Vol. 235, March 20, 1987, p. 1467-1472.

2. "Petroleum Research Centers," Philip H. Abelson, Science, Vol. 237, July 10, 1987, p. 117.

3. "U.S. Dependence on Oil Imports is Shooting Up But Congress, White House Fumble With Policy," Robert E. Taylor, The Wall Street Journal, June 19, 1987.

4. "Energy Futures," Philip H. Abelson, American Scientist, Vol. 75, November-December, 1987, p. 584-593.

5. "Recent Progress in Direct Coal Liquefaction," Robert E. Lumpkin, Science, Vol. 239, February 19, 1988, p. 873-877.

6. "The Seventh International Coal Utilization Technologies Survey," Battelle, Columbus Division, November 30, 1988, p. 4.

7. "Annual Energy Outlook 1987, with Projections to 2000," (DOE/EIA-0383(87) Energy Information Administration, U.S. Department of Energy, p. 38.

:0012I

Statement by C.W. Schultz, Acting Director
Mineral Resources Institute
University of Alabama

to

The House Space, Science and Technology Committee
Subcommittee on Energy Research and Development
Fiscal 1990 Hearings for
The Department of Energy Fossil Energy Programs

February 22, 1989

This testimony pertains to FY 1990 Department of Energy Research and Development authorizations for oil shale research. The University of Alabama strongly endorses the continuation of specific research on Eastern oil shale at a funding level of $8.0 million.

The Mineral Resources Institute at The University of Alabama conducts mineral and energy related research which responds to state, regional, and national needs. MRI also supports The University's strong commitment to education and training by providing an opportunity for graduate and undergraduate students to participate in a broad range of research projects in the mineral sciences.

One of the important national needs to which MRI has responded is the need to develop the immense energy resources represented by the Devonian-Mississippian oil shales. These formations underlie much of the Central and Eastern United States including specifically the States of Alabama, Tennessee, Kentucky, Indiana, Ohio, and Michigan. In 1975 the U.S. Geological Survey estimated that the Eastern oil shales contain 2.6 trillion barrels of recoverable oil. In a more recent study a single four county area of Northern Alabama and South central Tennessee has been shown to have reserves of 2.9 billion barrels at or near the surface. Certainly reserves of this magnitude must be a part of any long range plan for energy independence.

Supporting research to achieve and maintain energy independence is clearly one of the responsibilities of the federal government. This subcommittee has been instrumental in establishing a federal Eastern oil shale program. Before congressional action was taken to fund research on this dormant but important energy source, very little was known about the Eastern oil shales. Now these deposits are part of our country's energy base. Specific Eastern oil shale research has now been initiated for such purposes as: expanding the national fossil fuel data base, hydroretorting studies, evaluation of pre-concentration by beneficiation, to identify the chemical composition of kerogen, to establish the primary and secondary reaction products and for determining gasification characterization of Eastern oil shale. That program now is proceeding under sponsorship of the Department of Energy and it is our view that $8.0 million funding should be provided in FY 1990 for continuing research to develop Eastern oil shale technology into a viable national energy source.

During the past eight years The University of Alabama has conducted research to develop technology specifically tailored to improving the extraction characteristics of the Devonian-Mississippian oil shales. The research program has included the application of physical beneficiation, chemical extraction and retorting technologies for obtaining maximum energy recovery, as oil or gas, from the shale. Early in the investigations the Mineral Resources Institute at The University made a major breakthrough in upgrading the shales by physical beneficiation. Results of that research were first reported in several papers presented at the 1981 Eastern Oil Shale Symposium in Lexington, Kentucky.

A second major breakthrough in the technology of extracting oil from the Eastern oil shales was made by the Institute of Gas Technology (IGT). IGT, through its subsidiary HYCRUDE, introduced the concept of hydrogen retorting which effectively doubles the oil yield of Eastern oil shales.

These technologies, beneficiation, and hydroretorting were integrated in a program initiated in 1985 and completed only last month. The MRI role in this research program has been directed to upgrading Eastern oil shale by flotation, a standard mineral processing technique. Flotation methods are presently used in over 90% of the mining operations in the country to beneficiate our Nation's ore deposits. The MRI flotation research conducted under a DOE contract has shown the technique is also applicable to almost all the Eastern oil shales. Although flotation does not produce a marketable oil product from the shale, it can be used as a preconcentration step in the oil recovery process to reject the unwanted minerals components in the shale. By the addition of this preconcentration step, the flotation process reduces the follow-up retorting plant size (and cost) while also reducing the sulfur content of the retorted shale.

Beneficiation technology on Eastern oil shale has advanced under the DOE research program at the Mineral Resources Institute. Testwork on seven different Eastern oil shales have shown that this preconcentration method is applicable to a wide range of shales with diverse characteristics. By using standard flotation techniques, concentrates of Eastern oil shale have been made that contain 24 gallons per ton from a shale that was only 10 gallons per ton in the natural deposit. Approximately 85% of the oil is recoverable. Further research on the beneficiation process increased the concentrate grade to over 30 gallons per ton without any loss in the oil recovery. The most recent studies using new and innovative flotation methods indicate that concentrates approaching 50 gallons per ton can be achieved with yields exceeding 90%. Optimization of the flotation process is continuing with emphasis on still further increasing the process efficiency and reducing costs. A feasibility study conducted by a major engineering firm has shown that the preconcentration flotation step will reduce the overall cost of producing oil from hydroretorted Eastern shales. This study was only completed a month ago and is part of the present DOE Eastern oil shale program.

Today, under the leadership of the Institute of Gas Technology a comprehensive Eastern oil shale program, utilizing the systems concept, is in progress. In the "systems concept", a multidisciplinary team has been formed and is presently conducting coordinated research to develop pressurized fluidized bed hydroretorting (PHF), a new and innovative oil shale technology. The lead on this research team is the Institute of Gas Technology, Chicago, Illinois who originally developed PHF. The other team members are the University of Pittsburg, Ohio State University, Tennessee Technological University, University of Michigan, Illinois Institute of Technology and The University of Alabama Mineral Resources Institute. This group of research specialists are examining all aspects of the PHF technology including the associated activities of gas clean-up, environmental mitigation, shale oil upgrading and preconcentration by beneficiation.

Research results of the PHF process and its beneficiation component have been very encouraging. Indications are that this process will be the most economic and reliable technology for recovering oil from the Eastern shales. PFH is ideally suited for processing beneficiated shale because of the fine size of the material which will be subjected to hydroretorting.

To further advance this exciting technology beyond bench testwork and conceptual design, it is necessary that the process be demonstrated on a larger and continuous scale. We recommend that a four (4) ton per hour movable processing PHF unit (including a beneficiation preconcentration step) be designed, constructed, and operated at various Eastern oil shale sites. We support the IGT recommendation for $8.0 million in the Department of Energy budget for FY 1990 to develop technology for the production of oil from the Eastern shales. Of this amount, $3.0 million would be used to continue research on the PHF process and $1.5 million for the initial design of the four (4) ton per hour demonstration unit. The University of Alabama strongly urges continuation of the DOE Eastern oil shale program which to date has improved the economics of recovering oil from the Eastern shales and advanced the technological base of this Nation's fossil fuel resources.

Thank you for your consideration of my views on this important issue: our country's energy supply.

STATEMENT OF DAVID O. WEBB, SENIOR VICE PRESIDENT
POLICY AND REGULATORY AFFAIRS
GAS RESEARCH INSTITUTE
ON THE DOE FY 1990 GAS-RELATED RESEARCH BUDGET
BEFORE THE SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
SCIENCE, SPACE, AND TECHNOLOGY COMMITTEE
U.S. HOUSE OF REPRESENTATIVES

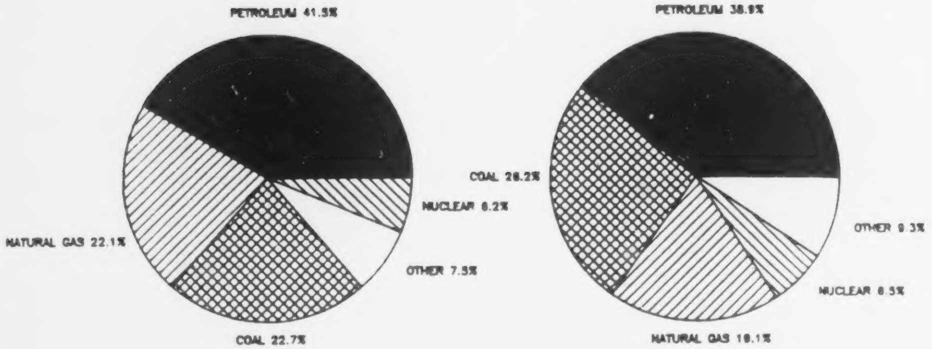
I appreciate the opportunity to appear before you today to present Gas Research Institute's (GRI) recommendations for gas-related research in the Department of Energy's (DOE) FY 1990 Fossil, Conservation, and Solar and Renewables R&D programs. The recommendations reflect the minimum funding required for a viable gas research program in DOE. In developing these recommendations, GRI gave top priority consideration to the need to develop the United States' extensive domestic gas resources to reduce our dependence on imported oil and the critical role gas can play in helping to solve some of our environmental problems. In this light, GRI and the gas industry have agreed upon a recommendation of $125.8 million for gas-related research in DOE's FY 1990 Fossil Energy, Conservation, and Solar and Renewables programs: $73.4 million for fossil energy R&D, $29.5 million for conservation R&D, $13.4 million for renewable energy R&D, and $9.5 million for a natural gas vehicle R&D program. Central to the gas industry's recommendation is that GRI is planning to commit $112.4 million to research in the same programs. Essentially, GRI is proposing that DOE's gas-related budget in FY 1990 approximately equal GRI's research budget in these same program areas.

GRI is an independent, not-for-profit scientific research organization that plans, manages, and finances a cooperative R&D program for the benefit of its 304 members and their customers. The R&D program is implemented through contracts with research organizations, engineering firms, universities, energy companies, and manufacturers. National energy R&D policy is a major factor influencing the R&D program since GRI cofunds and coordinates many of its research projects with DOE. GRI estimates it will coordinate $30 million of research with DOE in gas-related programs in 1990. Therefore, congressional action on the proposed FY 1990 budget has a direct impact on the gas industry's R&D program.

U.S. ENERGY OUTLOOK

The necessity of continuing a viable gas-related federal energy R&D policy becomes evident when we examine where the U.S. is projected to get most of its energy supplies over the next 25 years. U.S. actual primary energy consumption in 1987 relied on gas and oil to meet 63 percent of demand. GRI's projections indicate that in the year 2010, the U.S. will still get 58 percent of its energy from oil and gas. (See Exhibit 1.)

Exhibit 1
U.S. Primary Energy Consumption



1987 ACTUAL PRIMARY ENERGY CONSUMPTION *
(TOTAL 79.3 Quads)
*Source 1988 GRI BASELINE PROJECTION

2010 PRIMARY ENERGY CONSUMPTION*
(TOTAL 99.8 Quads)

Last year the American Petroleum Institute released a report that showed the number of wells drilled in search of oil and gas in 1987 declined more than 10 percent from 1986 levels and more than 60 percent from the drilling peak of 91,000 wells in 1981. By 1986 only 35,000 wells were drilled. U.S. oil production plummeted by 400,000 barrels a day during 1987 to a total of 8.28 million barrels per day. Meanwhile, U.S. consumption increased by 300,000 barrels per day, or by more than 5 percent. The reduced production and increase in consumption are forcing the United States into an even greater dependence on foreign oil, most of which is susceptible to disrupted availability. Imports now account for approximately 43 percent of U.S. consumption. This is the highest oil import level since the end of the 1970s.

While it is unreasonable to assume that the U.S. can become completely energy independent in the near- or mid-term, several options are available to ease the high import level. One obvious option is to substitute natural gas in viable areas that are currently adding to the oil imports. These include natural gas vehicles, combined-cycle power generation, cogeneration, and many commercial- and residential-size heating and cooling applications, to name a few.

The U.S. natural gas resource base is huge. With advances in technology, gas will maintain an important role in a highly competitive future U.S. energy mix well into the next century (See Exhibit 2). This future depends on continuing funding for a viable federal/gas industry research program to produce the technology base necessary to develop plentiful cost-competitive gas supplies and more efficient appliances, equipment, and gas processes. Developing this technology base requires a 10- to 15-year lead time and DOE's and the gas industry's joint effort.

Exhibit 2
Total United States Gas Reserves and Resources 1/

	Technically Recoverable Gas, Tcf	Recoverable Gas by Price	
		$3/Mcf	$3-$5/Mcf
Lower 48 (Conventional)			
Proved Reserves	159	159	--
Inferred Reserves	227	164	18
Gas Resources Associated with Oil	61	30	11
Undiscovered	353	142	87
Subtotal	**800**	**495**	116
Lower 48 (Unconventional)			
Gas in Low-Permeability Reservoirs	180	70	49
Coalbed Methane	48	8	4
Shale Gas	31	10	5
Subtotal	259	**88**	58
Alaska			
Reserves	33	7	0
Inferred	96	5	2
Subtotal	129	12	2
Total	1,188	595	176

1/An Assessment of the Natural Gas Resource Base of the United States, prepared by Argonne National Laboratory for U.S. Department of Energy Office of Policy, Planning, and Analysis, May 1988

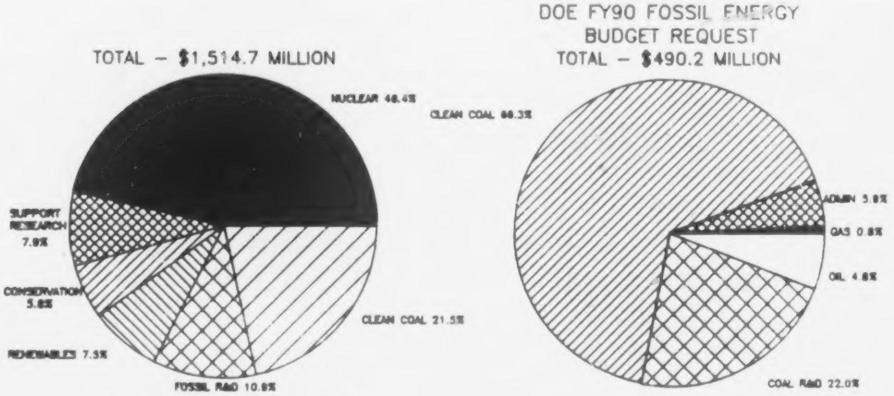
DOE ENERGY POLICY STATEMENTS VS. BUDGET REALITY

In February 1988 DOE announced a major new study to perform a comprehensive assessment of U.S. natural gas reserve potential. In announcing the study, Secretary Herrington stated, "Our growing dependence on imported oil is an Achilles heel." He further stated, "This is an opportune time to reassess the role natural gas can play in displacing imported oil."

The DOE Energy Security Study released last March concluded U.S. oil imports will probably increase substantially by 1995. Projections range from 8 million to 10 million barrels per day. The study also concluded that abundant domestic natural gas is the fuel that is most readily substitutable for oil. The study indicates targeted R&D in unconventional gas is one critical step to reducing U.S. dependence on imported oil.

Also, last May DOE performed a detailed assessment of total gas reserves and resources. The results (see Exhibit 2) show that over 1000 Tcf of gas is technically recoverable with approximately 600 Tcf recoverable by using advanced technology at prices of $3/Mcf. Included in this recoverable gas is 85 Tcf in unconventional reservoirs. Notwithstanding these DOE study findings, the DOE FY 1990 budget request is totally inconsistent with policy and the gas potential. The total budget request for gas-related research in DOE's Fossil and Conservation programs is only $32.24 million, a reduction of 62 percent from the $85.5 million Congress appropriated last fall. The request for unconventional natural gas R&D is only $4.1 million, less than 1 percent of the proposed Fossil Energy budget. The budget does not support the policy of allowing gas to play an important strategic role in reducing U.S. dependence on oil imports and solving environmental concerns. (See Exhibit 3.)

Exhibit 3
DOE's Program Is Out of Balance When Compared With
the Present and Future Energy Needs of the Nation



1990 DOE R&D FUELS BUDGET REQUEST
(EXCLUDING BASIC R&D, DEFENSE,
WASTE AND REMEDIAL ACTION,
AND BUSINESS ENTERPRISES)

PROPOSED JOINT DOE/GAS INDUSTRY GAS RESEARCH PROGRAM

An expanded joint effort between the gas industry and DOE is needed to ensure a stable, reliable energy mix for this nation's security. To maintain this joint effort, GRI recommends $125.8 million for DOE's gas-related research budget in Fossil Energy, Conservation, and Solar and Renewables programs. In many cases, these projects are being coordinated or cofunded with gas industry funding. GRI encourages greater use of cooperative R&D ventures to conduct much of this research especially in CNG vehicles, geosciences, unconventional natural gas, and residential/commercial space heating. Congress has recognized the need for a viable DOE gas-related program and has appropriated approximately $100 million each year for these DOE programs. (See Exhibit 4).

Exhibit 4
Gas-Related Research Recommendations
for DOE FY 1990 Fossil Energy and Conservation Programs
($ Millions)

	FY 1988 Approp.	FY 1989 Approp.	FY 1990 Gas Industry Recommend.	GRI Planned Budget 1990 1/
Fossil Energy				
ARTD (Gas-Related)	$ 6.0	$ 6.00	$ 6.0	$11.4
Fuel Cells (Gas-Related)	20.5	17.03	36.5	3.5
Coal Gasification	24.2	23.82	5.9	1.9
Combustion Systs. Emission Control	0.0	0.00	2.0	5.2
Heat Engines (Gas-Fueled)	3.0	3.00	8.0	5.5
Unconventional Natural Gas	10.9 2/	12.38 2/	15.0	36.8 3/
Fossil Energy Subtotal	**$64.6**	**$62.23**	**$73.4**	**$64.3**
Conservation R&D				
Heat Pumps & Prime Movers	$ 5.8	$ 6.600	$10.0	$11.3
Industrial Cogeneration	5.0	4.600	0.0	0.0 4/
ECUT (Gas-Related)	8.9	13.420	8.5	15.5
Indoor Air Quality/Bldg. Systs. Research	1.9	1.390	3.0	4.2
Desiccant Systems	0.7	1.265	8.0	6.9
Natural Gas Vehicles	0.0	0.000	9.5	6.4
Conservation Subtotal	**$22.3**	**$27.275**	**$39.0**	**$44.3**
Solar and Renewables R&D				
Biofuels (Gas-Related)	$ 8.5	$ 6.5	$ 5.0	$ 3.8
Geopressured Resources	5.0	6.0	8.4	0.0
Solar and Renewables Subtotal	**$13.5**	**$12.5**	**$13.4**	**$ 3.8**
Total--Fossil Energy, Conservation, & Renewables	**$100.4**	**$102.01**	**$125.8**	**$112.4**

1/Preliminary estimate--not yet FERC-approved
2/Includes geoscience activities
3/Includes $3.6 million for geosciences
4/Heat Pumps & Prime Movers budget includes $2.5 million for Industrial Cogeneration

The GRI planned budget for 1990 in Exhibit 4 reflects only a partial picture of the gas industry's R&D effort. GRI's total 1990 R&D budget is $153.5 million. The R&D program includes supply, end use, gas operations, and crosscutting research (see Exhibit 5).

Exhibit 5
GRI R&D Programs

	1989		1990*	
	Budget ($M)	Percent	Budget ($M)	Percent
Supply Options	39.97	27.2	44.52	29.0
End Use	80.95	55.2	81.79	53.3
Gas Operations	20.28	13.8	21.59	14.1
Crosscutting Research	5.50	3.7	5.60	3.6
	146.70	100%	153.50	100%

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*Preliminary estimate--not yet FERC-approved

GRI's R&D program helps to assure, both now and in the future, the widest use of natural gas that is consistent with a least-cost energy strategy. Major emphasis is placed on the development of technologies that have the potential to increase the efficiency of using natural gas in existing applications, and that are critical to new, cost-effective applications in which economic or other advantages can be identified. More specifically, GRI's program is designed to:

1. Decrease the cost of producing and delivering gas;
2. Enhance the role of gas in providing least-cost energy services, recognizing the importance of maintaining and increasing the superior quality, convenience, safety, and reliability of gas energy service at competitive prices;
3. Facilitate the transfer of new technology and technical and scientific information to the gas industry and its customers; and
4. Stimulate innovation in gas-related technologies through a mission-oriented basic research program.

RECOMMENDED GAS POLICY INITIATIVES

1. Establish an Office of Assistant Secretary for Natural Gas and Oil

In order for natural gas and oil to assume a more vital and important role in government energy policy, it is time for greater emphasis to be placed on activities related to natural gas and oil. GRI supports the gas industry's proposal to the Administration to create the post of Assistant Secretary of Natural Gas and Oil within DOE. This official would have overall responsibility for coordinating gas and oil research and policy within DOE and the government as a whole.

Natural gas and oil provide over 65 percent of current U.S. energy and are projected to provide over 50 percent of U.S. energy in 2010. Yet the DOE Fossil Energy budget devotes less than 6 percent of its funding to R&D for these two resources. We must have a better balance between U.S. energy use and energy R&D funding if the U.S. is ever going to develop a rational energy policy. The establishment of an Office of Assistant Secretary for Natural Gas and Oil would demonstrate a commitment to a rational energy policy and would promote the visibility and public understanding that gas and oil issues require.

2. Increase Geoscience Funding

GRI believes that in addition to increasing traditional energy R&D dollars, DOE needs to reevaluate its basic energy research goals and address a hydrocarbon geoscience research program. The increased oil and gas budgets for geoscience-type research is a step in the right direction. However, more needs to be done.

For the next 25 years, GRI estimates that oil and gas will provide over 50 percent of U.S. energy needs. Almost all the domestic oil and gas production by 2010 will have to come from fields and reservoirs not yet discovered and/or enhanced recovery technologies to produce the nearly two-thirds of the oil currently left in the ground. Whatever is not produced from these domestic discoveries will have to be satisfied by imported oil, primarily from OPEC nations.

Recent DOE actions to ~~establish a~~ geoscience office in Fossil Energy are encouraging. However, funding is required to implement an R&D program. GRI recommends DOE commit a total of $20 million in FY 1990 with $10 million designated for gas-specific research. This funding should be established as a separate line item in Fossil Energy.

3. Continue and Expand Cooperative R&D Ventures

GRI encourages DOE and Congress to continue and to expand the concept of cooperative R&D ventures. We believe the current cooperative R&D venture with GRI, the State of Texas Bureau of Economic Geology, and DOE in secondary gas recovery is working well. The most effective technology transfer occurs when industry is involved early and substantially in a research and development effort. The more directly the research agenda is guided by the companies' own technological and economic needs, the more effective transfer is likely to be.

While the cooperative venture concept is still a relatively new approach to government-industry financial partnerships, it is one that gives the private sector greater incentive to carry out research programs that are responsive to its R&D needs. Through industry's willingness to invest its own resources (at least 50 percent of the project funding), the research is managed and directed in a responsible way. In short, a joint R&D venture offers a relatively low-cost route to innovative technology through pooling government and industry resources.

GRI particularly recommends cooperative R&D ventures in gas cooling technologies, geosciences, unconventional natural gas, natural gas vehicles, and heat engines. GRI is prepared to initiate discussions with DOE on cooperative R&D ventures in these technologies if Congress provides funds.

RECOMMENDED DOE FY 1990 GAS-RELATED RESEARCH

Budget request levels continue to be far below what is necessary to conduct critical gas-related R&D in fossil, conservation, and renewable energy, and Congress has consistently increased these budget areas to provide a consistent funding level for ongoing research. In order to attract industrial funding partners in this research effort, it is necessary to maintain a continuity in funding and support for these ongoing programs. In its recommendations for gas-related research, GRI and the gas industry have, for the most part, requested a maintenance of ongoing programs supported by Congress in the past. But as public attention focuses on environmental issues such as acid rain and global warming, it is time to increase R&D in those areas that address environmental needs. The gas industry, through GRI, is investigating technologies to reduce pollution and the greenhouse effect both through supporting technology development and by conducting generic environmental and safety studies to assess actual and potential environmental implications for existing and emerging gas technologies. Therefore, some increase over past years recommendations is shown in the gas industry's recommendation for FY 1990 for fuel cells, natural gas vehicles, and heat engines. This increase is tied to technologies which address environmental concerns.

Following is a recommendation for specific programs of particular interest to GRI.

FOSSIL ENERGY

	FY 1988 Appropriation	FY 1989 Appropriation	FY 1990 Recommendation
Western Tight Sands	$3.3 Million	$3.325 Million	$4.0 Million

Significant amounts of potentially recoverable natural gas exist in low-permeability sandstone formations located in sedimentary basins throughout the United States. Current information indicates that the total amount of economically recoverable gas from tight sands could be in excess of 500 Tcf. However, a combination of technical limitations and economic constraints prevent the widespread commercial exploitation of these resources. It is estimated that the development of advanced technologies and practices applicable to tight gas sands could provide an additional 200 Tcf of cost-competitive gas over what is recoverable with the present state-of-the-art technology.

Gas-bearing tight sands occur in the form of blanket-type and lenticular formations. In both types, the effects of a variety of interdependent parameters are still unknown, and consequently, the gas recovery rate and active reservoir life for a given field remain uncertain. To permit low-cost exploitation of the full potential of the tight sands resource base, the following specific technological issues need to be addressed:

1. Determine the relationship between geologic and engineering parameters;

2. Further characterize tight sands gas reservoirs and improve resource estimates;
3. Identify the parameters critical to formation evaluation and gas production;
4. Understand more clearly the mechanisms of hydraulic fracture propagation and control;
5. Diagnose fracture shape and downhole conditions using surface parameters;
6. Provide real-time fracture treatment design changes; and
7. Apply advanced technologies to presently noncommercial areas.

Geotechnical and economic analyses have demonstrated that blanket-type formations are more amenable in the near term because the geologic environments in which they exist are less complex than the environments associated with lenticular formations. Therefore, GRI has concentrated its efforts in the near-term aspects of blanket-type formations such as resource characterization, formation evaluation, fracture diagnostics, and real-time analysis development. In addition, in 1989 GRI plans four staged field experiments to validate technologies developed in this project area. GRI's planned 1990 budget for tight gas sands is $10.9 million. In addition, it is expected that industrial partners will contribute another $4.25 million. GRI recommends that DOE commit $4.0 million for longer-term research in the lenticular formations.

Eastern Devonian Shales	FY 1988 Appropriation	FY 1989 Appropriation	FY 1990 Recommendation
	$2.3 Million	$3.075 Million	$4.0 Million

The large eastern Devonian gas shales resource base underlies approximately 175,000 square miles of the Eastern United States. Current information indicates that the gas-in-place is approximately 2000 Tcf; however, large uncertainty exists regarding how much of that resource may be recoverable. There is approximately 120 Tcf of gas-in-place in a drillable area of 22,000 square miles in the heart of the Appalachian Basin, and projections indicate that up to 50 Tcf of gas may be technically recoverable.

In general, two major factors constrain present-day exploitation of this resource: (1) the inability to predict with confidence the gas production rates that will be obtained in wells drilled outside of historical production areas, and (2) the inconsistent response of formations to currently employed stimulation practices. Because most of the producers in the Appalachian Basin are small independents, they cannot afford to conduct the comprehensive R&D required to understand and solve these problems.

Barriers to economic production of natural gas from Devonian shales include:

1. Inadequate understanding of factors that control the flow of gas from Devonian shale formations to the wellbore;
2. Lack of effective exploration rationales to identify geographic areas and stratigraphic zones with highest production potential;
3. The need for improved diagnostic methods to assess the potential of productive zones;
4. Inadequate understanding of shale gas reservoir dynamics; and
5. Lack of generally effective stimulation techniques.

Economic exploitation of the full resources hinges on development of improved techniques and technologies for overcoming these limiting factors.

GRI's program in eastern Devonian shales includes reservoir evaluation, recovery enhancement methods, geologic production controls, and development of a resource well information data base. GRI's planned 1990 budget for eastern Devonian shales is $5.5 million with an additional $1.1 million in industrial funding expected. The gas industry recommends a total of $4.0 million for DOE research of eastern Devonian shales.

Secondary Gas Recovery	FY 1988 Appropriation	FY 1989 Appropriation	FY 1990 Recommendation
	$2.5 Million	$2.5 Million	$3.0 Million

A significant quantity of natural gas requiring minimal exploration and in close proximity to gathering systems and pipelines is known to exist in currently producing and abandoned wells and fields. These potential reserve additions consist of (1) bypassed gas in currently producing or temporarily abandoned wells, (2) reservoir compartments in existing fields, and (3) gas trapped by the encroachment of water in water-drive reservoirs.

To ensure the timely development of technologies for near-term production of bypassed gas and gas from undiscovered reservoir compartments in developed fields, the following specific technological issues need to be addressed: (1) improved understanding of geologic environments and characteristics of gas fields to allow for more accurate resource identification and estimates, (2) provision of an accurate methodology for cased-hole formation evaluation, and (3) development of in-field reexploration rationales based on a better understanding of reservoir heterogeneities. By addressing these issues, gas producers can exploit appropriate elements of the conventional resource base in the near term at market-clearing prices. Over the longer term, application of these technologies can increase gas reserves and deliverability of low-cost gas through more effective and efficient development of fields yet to be discovered.

In addition to bypassed gas and gas from undiscovered reservoir compartments in developed fields, an estimated 500 Tcf of technically recoverable natural gas (50 Tcf of which is estimated to be economically recoverable) exists in water-drive reservoirs in the form of trapped gas. The gas becomes trapped as a result of the encroachment of water into production wells and the inability to maintain low reservoir pressure due to high water influx into the reservoirs. Once high levels of water production are reached, the traditional production practice is to plug and abandon the affected gas wells and ultimately the gas field. Recent data have indicated that the recovery efficiencies for the prolific water-drive gas reservoirs along the Texas-Louisiana Gulf Coast are now recognized to be 50 percent or less.

Specific technological issues that need to be addressed include:

1. Improving the understanding of geologic environments and characteristics of gas fields to allow for resource identification and estimates;

2. Providing a methodology for cased-hole formation evaluation; and

3. Developing in-field reexploration rationales based on an understanding of heterogeneities.

Currently, GRI's program addresses resource characterization, coproduction of trapped gas and water, and brine treatment and control. An initiative undertaken in 1988 was research into the undiscovered reservoirs in known fields. This Secondary Gas Recovery program is cofunded with the Department of Energy, GRI, the State of Texas Bureau of Economic Geology, and producers under a cooperative R&D venture.

GRI's planned 1990 budget for secondary gas recovery is $6.7 million with an additional $3.0 million expected from industry. The recommendation to DOE is $3.0 million.

Underground Coal Gasification	FY 1988 Appropriation	FY 1989 Appropriation	FY 1990 Recommendation
	$2.825 Million	**$1.371 Million**	**$2.5 Million**

Underground coal gasification offers a method for recovering coal resources, without the need for mining, by gasifying the coal in-place underground. Oxygen, in conjunction with steam, is injected into an underground coal bed to drive and control the gasification reactions. As a potential source of cost-competitive pipeline-quality gas, in situ coal gasification may be able to tap those vast coal deposits that would not normally be economically recoverable using existing or anticipated strip- or deep-mining methods. Underground coal gasification is, therefore, applicable to a different coal resource base than surface gasification. In comparison with present-day surface gasification processes, underground technology offers a projected 15 to 35 percent cost savings as well as possible environmental and safety advantages.

At the present time, underground coal gasification must be classified as a high-risk, advanced technology, but one with very high payoff potential. This high payoff would be due at least in part to the very large potential resource base to which this technology can apply. DOE has estimated that, of the current 6.4 trillion tons of domestic coal resources, only about 0.5 trillion tons are currently economically recoverable by existing surface- and deep-mining techniques. Underground coal gasification could potentially utilize about 1.8 trillion tons, producing more that 1000 Tcf of substitute natural gas, even if only 10 percent of this resource is suitable for gasification.

Major challenges confronting successful development of in situ gasification include: (1) the verification of low-cost, reliable, reproducible methods for providing a pathway linking injection and production wells; (2) control of the combustion front and gas quality; and (3) prediction and mitigation of subsidence potential and other environmental impacts. In particular, additional R&D is needed to further prove the applicability and reliability in the field of the low-cost, controlled-retracting-injection-point (CRIP) concept developed by Lawrence Livermore National Laboratories. This concept provides the capability of reducing cavity and roof interactions (which can decrease gas quality during the burn) by controlled relocation of the burn cavity within the coal seam when cavity/roof interactions begin. The first large-scale test of the CRIP technology--a 30-day test at Centralia, Washington, under DOE and gas industry sponsorship--was successfully completed in 1983. A large-scale test (conducted for 100 days by GRI as the head of an industry consortium in conjunction with DOE at Hanna, Wyoming, during late 1987 and early 1988) assessed the technology further. The test results defined the viability of the CRIP process for the cost-effective recovery of subbituminous unmineable coals in flat coal seams.

Continued DOE support is needed to do post-burn coring and generic environmental work at the Rocky Mountain I site, analysis of RMI data by Lawrence Livermore National Laboratory, completion of treatment of the abandoned Hoe Creek UCG site, and planning for follow-on UCG environmental research.

GRI's 1989 budget for underground coal gasification is $725,000, and GRI's planned budget for 1990 is $450,000. The recommendation for DOE's FY 1990 budget is $2.5 million.

Fuel Cells (Gas-Related)	FY 1988 Appropriation	FY 1989 Appropriation	FY 1990 Recommendation
	$20.45 Million	$17.034 Million	$36.5 Million

A fuel cell uses natural gas in an electrochemical process to produce electricity and heat. This is accomplished with very high overall energy efficiency, good reliability, low noise, and virtually no pollutants. The gas utility industry, in cooperation with other parties, has supported the development of onsite phosphoric acid fuel cells for the past two decades as alternatives to existing prime-mover-powered cogeneration systems for use in commercial and industrial cogeneration applications. Two developments have made clear that the technology base for an early-entry fuel cell power plant is presently well defined: (1) the successful field testing (from 1983-1986) of 46 40-kW fuel cell systems and (2) the decision by the participating manufacturer to commercially offer larger phosphoric acid fuel cell (200-kW) power plants for delivery starting in 1990 or 1991. R&D is still warranted, however, to reduce the capital cost and increase the performance and durability of phosphoric acid fuel cell systems to levels acceptable for commercial viability. Early-entry systems of this type will serve to introduce the fuel cell concept to a wide range of potential users.

Advanced fuel cell technology, currently being addressed by several organizations worldwide, offers three important operating benefits compared with phosphoric acid fuel cells: (1) electrical efficiencies of 45 to 63 percent (compared with 36 percent for phosphoric acid fuel cells), (2) higher temperature operation (1300°-2000°F vs. 400°F) offering higher-quality thermal energy, and (3) ability to use natural gas directly without extensive reformer equipment. Two types of advanced fuel cells appear promising: the solid oxide (ceramic) fuel cell (SOFC) and the carbonate fuel cell (CFC). SOFC technology is promising because of its potential for high-power-density cell stacks, its solid state construction which eliminates the liquid electrolyte, and its potential as a simpler and less expensive system than the carbonate type. Major R&D efforts are needed, however, on cell fabrication technology and durability before detailed SOFC system development can be undertaken.

Research on CFC technology is being conducted by several organizations in the United States and Japan for use primarily on central-station electric generation. GRI has monitored the progress being made in this research, especially with regard to potential application of carbonate technology in an onsite cogeneration system. Although the development of CFCs has proceeded further than solid oxide systems, major development efforts are still needed in the cell stack area (power section) before the CFC can be commercialized. These efforts include activities that have long development times and represent major technological hurdles: electrode performance and durability, electrolyte management, corrosion, thermal cycling, integration of stack components, and improved fabrication technologies.

GRI's planned 1990 budget for fuel cell activity is $3.5 million with an additional $3.4 million from industrial partners. The gas industry recommends a DOE budget of $36.5 million for molten carbonate and solid oxide fuel cells and for a generic program in phosphoric acid fuel cells.

CONSERVATION

	FY 1988 Appropriation	FY 1989 Appropriation	FY 1990 Recommendation
Heat Pumps	$5.8 Million	$5.8 Million	$10.0 Million

For a typical cold-climate residence, the gas heat pump can provide both heating and cooling in a single unit using less energy than a conventional (70-percent-efficient) gas furnace would use for heating alone. Current performance estimates suggest that in heating, the gas heat pump could save up to one-half the natural gas now used by a conventional furnace or one-fourth the energy used by a high-efficiency (90-percent-efficient) furnace. The gas heat pump can also be a cost-effective alternative to electric cooling in regions where the cooling load is significant and the electric-to-gas price difference is high. In addition, the gas heat pump could fill the summer "valley" for gas utilities while also substantially reducing summer peak demands for electricity, thereby favorably impacting operating costs for both gas and electric utilities.

Development of the gas heat pump, however, faces several major challenges. Initial cost of the gas heat pumps being developed by GRI is estimated to be up to 15 percent higher than that of other space-conditioning options such as electric heat pumps or combination gas-furnace/electric-air-conditioning systems. Consumers are still sensitive to the first-cost difference among competing products even though they are increasingly aware of economic decision criteria such as payback and return on investment. In selected applications, the lower operating cost of the gas heat pump can offset its high first cost; however, the economic merit of the gas heat pump will be very sensitive to the magnitude of heating and cooling loads as well as the difference in gas and electricity prices.

Achievement of gas heat pump targets for life-cycle cost and payback requires substantial technical advancements, particularly in engine and/or advanced absorption technologies, to improve first cost, efficiency, life, maintenance frequency, and maintainability.

GRI's program is focused on developing gas heat pump technologies most appropriate for near-term market entry, with active support and participation by both the HVAC manufacturers and gas utilities in the R&D activity as early as possible. Based on past GRI efforts, the technologies now considered most promising for near-term market entry include: (1) a dual cycle absorption heat pump using existing fluids with an advanced heat-exchange subsystem, (2) an engine-driven heat pump using available internal combustion engine technology modified for high reliability and long life, and (3) an advanced adsorption heat pump.

GRI's planned 1990 budget for residential and commercial heat pumps is $11.3 million with an additional contribution of $4.3 million expected from industrial partners. A budget of $10 million is recommended in DOE's technology and consumer products budget.

NG Cooling/Desiccants	FY 1988 Appropriation	FY 1989 Appropriation	FY 1990 Recommendation
	$ 70,000	$1.265 Million	$8.0 Million

In cooling applications a variety of technical challenges must be overcome to make more competitive technologies available. High latent-load applications and air-conditioning in high ambient humidity areas represent opportunities for desiccant-based dehumidification and cooling systems. Needed desiccant improvements include higher performance, reduced equipment size, and improved understanding of the capability of desiccants to remove airborne pollutants as well as moisture.

In desiccant technology, warm air from a gas burner is used to dry or regenerate the desiccant material which absorbs or removes moisture and thereby handles the latent cooling load. In buildings where moisture control and air quality are essential, desiccant cooling cycles offer a unique opportunity to attack moisture problems as well as air cleanliness.

GRI is currently developing advanced cooling/dehumidification systems for supermarkets, other commercial buildings, and residential buildings using both gas-regenerated desiccant and an electric air conditioner to provide optimum cost-effectiveness and comfort.

In another technology, Oak Ridge National Laboratory (ORNL) has initiated a program of absorber research with the installation and initial operation of two test loops for cooling: one for ammonia-based fluid systems and the other for water-based systems. The objective of this work is to develop a theoretical and experimental knowledge base that will facilitate the design of absorbers and the application of enhancement techniques. Successful completion of this work is expected to enable the design of more compact, more effective, and lower-cost absorbers and to reduce required R&D time and costs.

The absorber is a key component of absorption heat pumps and chillers. Absorption chillers have been in use for space conditioning applications for several decades. These devices have favorable energy use characteristics and economics when operating on waste heat, but are generally more expensive than electric chillers when operating on natural gas. A new generation of gas-fired absorption chillers is now being developed with support of organizations that include DOE, GRI, and a few gas utility companies. These systems have potential for operation at twice tne energy efficiency of conventional chillers; moreover, most of these systems can be designed as heat pumps that provide heating and/or cooling and can operate in the heating mode at twice the efficiency of the best furnaces and boilers. Advanced absorption chillers and heat pumps, if successfully developed and commercialized, have the potential to provide space conditioning for residences and commercial buildings at lower cost and reduced energy consumption compared with existing equipment. They will also provide seasonal load leveling for both gas and electric utilities.

The expanded use of absorption systems will also produce environmental benefits. In addition to reducing the national use of fossil fuels, their use of natural gas has the benefit of producing low CO_2 emissions per unit of energy consumed. Also, absorption systems do not depend on the use of ozone-layer-depleting chlorofluorocarbon refrigerants.

The absorption process is basically the absorption of a vapor, such as ammonia, into a liquid solution of water and dissolved ammonia. Heat is liberated in the absorption process and the solution must be cooled to keep the process going. The heat picked up by the coolant is used either to provide space heating or it is used beneficially elsewhere in the machine. While this phenomena does not sound complex, it involves simultaneous heat and mass transfer, a process that is not well understood scientifically. As a consequence, absorbers in use today have mostly been designed using a costly and time-consuming procedure. Moreover, the absorber is typically one of the largest and most expensive components of the system.

The development of the new advanced absorption machines requires the development of absorbers operating in new temperature and pressure ranges and possibly with new fluids. Time and costs for this work can be reduced with information gained from ORNL absorber research, and a better result can be expected.

One of the ORNL test loops is now being used to provide basic information on a new absorber design to one of ORNL's subcontractors developing an advanced absorption heat pump. In addition, a joint GRI/ORNL program is under development. However, to provide the full potential benefit of this research, support for a multiyear basic program is needed.

GRI's planned 1990 budget for desiccant cooling systems is $6.9 million with an additional $1.7 million expected from industrial partners. A budget of $8.0 million is recommended for DOE to address advanced cooling systems.

Energy Conversion and Utilization Technology (Gas-Related)	**FY 1988 Appropriation**	**FY 1989 Appropriation**	**FY 1990 Recommendation**
	$8.9 million	**$7.0 million**	**$8.5 million**

The advantages of structural ceramic materials versus metal alloys are well documented. Because ceramics are lightweight, retain their strength at high temperatures, and have high corrosion and wear resistance, they can increase complexity and reduce maintenance through the use of noncooled components, and they can increase equipment life due to improved corrosion and wear resistance. To help ensure that these potential benefits of ceramic materials are fully realized; however, R&D is needed to address several technical issues that have impeded wide market penetration.

The key elements used in ceramics manufacture--aluminum, silicon, zirconium, titanium, carbon, nitrogen, and oxygen--are relatively abundant and inexpensive. This is in marked contrast to the uncertain supply and cost outlook for some strategic metals common in the manufacture of high-temperature metallic components. However, labor-intensive fabrication techniques geared toward limited-volume production of ceramics have resulted in high component and system costs. Reliability and cost are particularly important issues in the production of large components with variable geometries. Research is needed to develop more systematic fabrication techniques for the forming and sintering of more reliable ceramic parts, and reproducible and cost-effective manufacturing and quality control techniques are needed for the large-scale production of reliable ceramic materials and components.

In 1986 GRI helped establish the Center for Advanced Materials (CAM) at Pennsylvania State University and signed a five-year, $10 million agreement to fund the center. The CAM serves to consolidate and coordinate the necessary resources and expertise to provide advanced materials suppliers, manufacturers, and end users with (1) concise, targeted information on advanced materials property and performance data, (2) material and component analytical and engineering services, and (3) applied material research to facilitate the use of advanced materials as accepted engineering materials. Efforts at the CAM provide a mix of near-term and long-term R&D targeted toward the needs of the gas industry, equipment manufacturers, and end users. The CAM capitalizes on coordinated funding from other sources and utilizes existing facilities and broad expertise to more cost-effectively achieve R&D goals.

In addition to ceramics work, important crosscutting research in the areas of combustion, biocatalysis, and tribology provide invaluable information and technological advancement for the gas industry.

GRI's planned 1990 budget in these areas totals approximately $15.5 million with an additional $4.7 million expected from industrial partners. The recommendation for gas-related research within the ECUT programs is $8.5 million.

	FY 1988 Appropriation	FY 1989 Appropriation	FY 1990 Recommendation
Natural Gas Vehicles	$ 0	$ 0	$9.5 million

In the late 1970s, increased gasoline and diesel fuel prices and related concerns about gasoline rationing generated renewed worldwide interest in natural gas as an alternative to gasoline and diesel fuel in stationary and mobile engines. Continued concern over the reliability of imported petroleum supplies also prompted several domestic and foreign automobile manufacturers to evaluate a broad range of fuel alternatives including natural gas. While the competitiveness of natural gas vehicles (NGVs) is extremely sensitive to assumptions about capital costs, fuel costs, and resale value, the potential market for these vehicles is appreciable. Several analyses of both vehicle usage patterns and existing institutional barriers to increase utilization of natural gas fuel have helped identify certain fleet vehicles as the most promising near-term application for the large-scale penetration of NGVs.

Recent environmental concerns have been an issue as well. The Environmental Protection Agency issued new standards for vehicles that immediately affect heavy-duty diesel vehicle fleets. These standards are "technology forcing" regulations, specifically, the 1991 limit for transit bus diesel particulate emissions of 0.1 G/BHP-HR (grams per brake horsepower-hour). This is beyond the state of the art for conventional diesel technology. A demonstration program would be beneficial to determine the contribution a natural gas vehicle or natural gas/diesel vehicle would make towards meeting EPA's regulations.

Environmental emissions from NGVs will depend on the degree to which engine calibration and hardware configurations are optimized to utilize natural gas. Currently, available exhaust emissions data are quite inconclusive with respect to the environmental benefits of natural gas as a vehicle fuel versus alternatives such as gasoline and methanol. This is particularly true of compression-ignition (diesel) engines converted to use natural gas and late-model spark-ignition vehicles using computer-controlled emission systems. There is a need for a comprehensive NGV emissions data base to help establish engine conversion kit research goals and to ensure that this technology remains an environmentally acceptable application of natural gas.

There is little data available today by which to determine the contribution natural gas/diesel engines might make in meeting current and future EPA standards. GRI is currently developing a retrofit kit and compiling some preliminary data to help determine the impact of natural gas use to meet these standards and to be used as a basis for demonstration of natural gas/diesel in two-stroke diesel engines which make up about 95 percent of the heavy-duty public transit vehicles. It is recommended that DOE address the cost of the vehicle conversion and the compression stations. Testing should be done in both northern and southern climates with six to ten heavy-duty vehicles in each station. A mixture of urban expressway and intracity buses is required with a minimum operation of 12 to 18 months.

GRI is currently funding research in advanced compressed natural gas (CNG) fueling system developments and enhanced CNG storage systems. In addition, GRI and a manufacturer are working on a cost-effective retrofit kit to permit dual-fuel or spark ignition natural-gas-only operation of existing two-stroke diesel transit buses to meet 1988 EPA standards. To meet the 1991 EPA standards, GRI is developing two natural gas engines--one a two-cycle, the other a four-cycle engine--to enable transit buses to comply with the regulations.

GRI's planned 1990 budget for natural gas vehicle research is $6.4 million with an additional $525,000 expected from industrial partners. A budget of $9.5 million is recommended for DOE in FY 1990 to pursue the natural gas vehicle technology.

SOLAR & RENEWABLES

	FY 1988 Appropriation	FY 1989 Appropriation	FY 1990 Recommendation
Biofuels (Gas-Related)	$8.5 Million	$6.5 Million	$5.0 million

The gas industry believes the gas-related research and development in biofuels being carried out at the Solar Energy Research Institute is in direct support of our industry's goals. Of particular value is the biotechnology process of anaerobic digestion of municipal solid waste which includes genetic and other improvement of biological organisms and development of innovative reactor design concepts. Continuation of cost sharing of the Community Waste Project at Walt Disney World, Florida, by the GRI and the DOE through the Solar Energy Research Institute is encouraged. This project has resulted in the construction and operation of the 1200 gallon digester at the experimental test unit (ETU). Work in the future should be directed to methods to decrease solids residence times, increase solids concentrations, and understand and control the biological populations in digesters. This work has the potential to provide technology that can produce methane for less than $3.50/MMBtu.

Another significant area of research at the Solar Energy Research Institute is methods to remove CO_2 from the air or from combustion plant stacks. Novel alternatives are under development either using microalgae or methyl catalysts as a scrubbing mechanism to remove CO_2 and convert it to fuels such as gasoline or methanol. The basis for using microalgae is that they are the most productive biochemical factories in the world--they consume 7 to 14 times more CO_2 than crop plants per unit land area. Two, one-quarter acre size microalgae ponds are already in operation at an outdoor test facility in New Mexico. Carbon dioxide in a processed combustion plant flue gas could be directly injected into pond water. Trapping efficiency is estimated to be at least 50 to 80 percent with current technology. The microalgae synthesize oils from the CO_2 and other nutrients and these oils can be converted to gasoline for fuel. Metal catalysts work by first adsorbing CO_2 from the atmosphere or from flue gases and then through a three-step process converting it to methanol. This research involves the synthesis of new metal catalytic compounds to remove CO_2 from air with high efficiency. In one year, compounds have been synthesized that are capable of being four times as efficient as existing systems. Excellent progress has been made on two of the three steps in the development of methyl catalysts to convert CO_2 to methanol. The third step is vital, and funds should be made available to undertake work in this area as well as improve further the other steps of the process. This approach has significant promise to aid in the greenhouse problem.

These projects have been funded by the Department of Energy but at levels well below those needed to make timely advances to benefit industry. Therefore, it is recommended that the FY 1990 biofuels budget be increased to $25 million with $5 million for gas-related research and development.

GRI's planned 1990 budget for biofuels is $3.8 million with an additional $550,000 expected from industrial partners. The recommendation for DOE's contribution to continue these program is $5.0 million.

SUMMARY

GRI recommends that the Department of Energy continue to fund a viable, consistent gas-related research program that adequately addresses the long-term needs of this nation's energy supply and environmental concerns. A total of $125.8 million would continue the programs Congress has already approved in past years and would address new environmental technologies (see Exhibit 6). We believe this budget recommendation is consistent with the realities resulting from the large budget deficit, the need for a balanced energy policy and the need for additional environmental research. It should be noted that the gas industry is funding near-term research in these program areas with a GRI R&D budget of approximately $112 million.

These central themes of funding adequate, long-term gas research in DOE while GRI funds near-term research and of strengthening the oil- and gas-related geosciences and environmental programs are sound national energy policies that Congress should implement.

Exhibit 6
Recommended DOE Gas-Related Budget for FY 1990 for Fossil, Conservation, and Renewables R&D
($ Millions)

	FY 1987 Approp.	FY 1988 Approp.	FY 1989 Approp.	FY 1990 Gas Industry Recommend.
Fossil Energy				
ARTD	$ 8.6	$ 6.0	$ 6.00	$ 6.0
Fuel Cells (Gas-Related)	14.9	20.5	17.03	36.5
Heat Engines (Gas-Related)	0.0	3.0	3.00	8.0
Surface Coal Gasification	24.6	21.4	22.45	3.4
Unconventional Natural Gas	8.1	10.9 1/	12.38 1/	15.0
Underground Coal Gasification (Technology Base)	2.4	2.8	1.37	2.5
Subtotal	$58.6	$64.6	$62.23	$71.4
Combustion Systems Emission Control (Clean Coal Tech. Fund)	15.0	0.0	0.00	2.0
Fossil Energy Subtotal	**$73.6**	**$64.6**	**$62.23**	**$73.4**
Conservation R&D				
Heat Pumps & Prime Movers	$ 5.0	$ 5.8	$ 6.600	$10.0
Industrial Cogeneration	5.0	5.0	4.600	0.0
ECUT (Gas-Related)	6.0	8.9	13.420	8.5
Indoor Air Quality	6.0	1.9	1.390	3.0
Desiccant Systems	0.0	0.7	1.265	8.0
Natural Gas Vehicles	0.2	0.0	0.000	9.5
Conservation Subtotal	**$22.2**	**$22.3**	**$27.275**	**$39.0**
Solar & Renewables R&D				
Biofuels (Gas-Related)	$12.1	$ 8.5	$ 6.5	$ 5.0
Geopressured Resources	4.0	5.0	6.0	8.4
Solar & Renewables Subtotal	**$16.1**	**$13.5**	**$12.5**	**$13.4**
Total--Fossil, Conservation, and Renewables	**$111.9**	**$100.4**	**$102.01**	**$125.8**

1/ Includes geoscience activities.

U. S. House of Representatives
Committee on Science, Space, and Technology
Subcommittee on Energy, Research, and Development

Hearing On
The DOE Fossil Energy Authorization

Statement by

John T. Whetten
Associate Director
Energy and Technology
Los Alamos National Laboratory
Los Alamos, NM 87545

Danny L. Hartley
Vice President
Energy Programs
Sandia National Laboratories
Albuquerque, NM 87185

February 22, 1989

SUMMARY

The Nation is becoming increasingly dependent on foreign oil imports (currently 40% of daily consumption). Oil imports are about one-third of our trade deficit, put our energy security at risk, reduce our foreign policy options, and cause economic downturn in oil producing regions of the U.S. Advanced technologies can help reduce imports by enabling more of the two-thirds of the oil normally left behind during production to be produced.

In response to this problem, Department of Energy Assistant Secretary J. Allen Wampler created the Oil Recovery Technology Partnership in October 1988 at Los Alamos and Sandia National Laboratories and provided initial funding of $1M for FY 1989.

The purpose of the partnership is to provide the oil industry with a mechanism to access Los Alamos and Sandia expertise, equipment, facilities, and technologies that could have near-term applications in improved oil recovery processes. These weapons laboratories have unique technologies in electronics, instrumentation, materials, computer modeling, expert systems, and other related areas. These technologies have been developed through defense-related research and therefore are not readily available through petroleum industry or university research. This partnership is consistent with other initiatives that encourage close involvement between industry and the national laboratories.

The partnership emphasizes these features:

1. An organizational structure and project management mechanism that includes U.S. industry (majors, independents, and service companies) up front to guide, evaluate and prioritize the collaborative R&D efforts, with special attention given to the needs of independents.

2. A commitment by the laboratories to emphasize the near-term spin-off of defense and energy-related technologies to significant problem areas currently hindering the improved production of oil from mature fields.

3. A commitment by the laboratories to coordinate closely with industry to assure that industry needs guide the development of enabling technologies and to incorporate industry expertise in applications, processing, and manufacturing.

4. An industry-guided project review mechanism.

5. A management structure for the partnership that will operate through the existing DOE Fossil Energy framework under the programmatic guidance and control of the DOE Bartlesville Project Office and the policy and administrative guidance and control of the DOE Albuquerque Operations Office.

Consistent with industry guidance, the partnership has identified crosswell seismics as a strategic technology area in which collaboration between laboratories and industry will advance the technology. Efforts have begun to assist an independent oil producer to improve the efficiency of a water flooding operation for enhanced oil recovery. Another independent producer is being assisted in the design and execution of well stimulation and well completion practices that should lead to improved oil production.

Industry response to the partnership has been excellent. Projected partnership activities for FY 1990 require a minimum of $5M. At this level of support, the oil industry will get a firm message that DOE (through its national laboratories) is committed to providing technical assistance for enhanced recovery of domestic oil.

I. INTRODUCTION—*What is the problem?*

In many respects, the energy situation in the U.S. in 1989 closely parallels the situation that developed in the early 1970s that led to a period of instability in the oil industry. The consumption of oil is on the increase, domestic production of crude is decreasing, exploration activities are decreasing, and the ever-increasing gap between consumption and production is being made up with imported oil. Unlike the 1970s, however, the oil industry in the U.S. has recently suffered through some of the worst years in its history. Revenues and profits have declined sharply and oil producers have been forced to reduce their staffs by laying off tens of thousands of skilled employees who cannot easily be replaced. This decline has propagated back to the universities in the form of decreasing student enrollments in geophysical sciences and reduced budgets for research and laboratory equipment. These events could jeopardize the ability of the domestic oil industry to respond to the next national oil crisis, and the resulting reductions in the technical base could be a long term problem.

With the current low oil prices, exploration activities and the development of new oil reserves have been substantially cut back. The oil field service industries are all laboring under the influence of these cutbacks and many service organizations have gone bankrupt during this difficult period. The fact that the health of the U.S. oil industry can be so seriously affected by the world oil price leads to a potentially hazardous scenario in terms of energy security for the future. The price of oil in the world market is extremely volatile and responsive to political activities in the Middle East.

Over 60% of the known oil reserves that can be recovered economically at today's prices are located in the region surrounding the Persian Gulf. Although the U.S. made an effort to reduce its share of imported oil from the Persian Gulf area, this trend is now reversing with the abundant supplies of low-cost oil available from OPEC countries.

As stated in the multi-agency report *Energy Security*, prepared by the Department of Energy (DOE) for President Reagan, "One crucial ingredient of U.S. energy security is a more competitive domestic oil industry that will continue to explore for and develop U.S. oil reserves. Under current low prices, exploration and production have fallen as the oil industry has retrenched. The industry needs to become more competitive... ." This report identified U.S. oil as "a resource at risk."

The U.S. is currently importing more than 40% of its daily petroleum consumption. Even at the low world oil price in effect today, this contributes more than $40 billion per year to our trade deficit. The trend continues to worsen; a substantial rise in imports took place during 1988. America's demand for oil continues to grow as its domestic production declines.

II. BACKGROUND—*Why do we have this problem?*

Because of its vigorous industrial base, its automobile-based transportation system, and its large population with an established infrastructure for utilization of oil, the U.S. consumes more oil than any other country. The U.S. consumption of oil is approximately one-third of the total free-world oil consumption. The U.S. transportation system alone uses more oil each year than the country produces. The U.S. also produces a large amount of oil. In 1985, the U.S. produced about one-fourth of the total free-world oil production—more than any nation on Earth except the Soviet Union. Although Saudi Arabia has the capability to produce more oil than the U.S., it is producing at less than half of its capacity.

Perhaps of even greater significance is the fact that U.S. oil costs more to find and produce than oil in other countries. Approximately 40% of the oil produced in the U.S. comes from very low productivity "stripper" wells, expensive offshore platforms in deep water, or harsh environmental regions such as the Alaskan north slope. The average crude oil production costs in the U.S. are almost 2.5 times the equivalent cost in the Middle East.

Some 12,000 independent oil producers form a critical element of the domestic petroleum industry. The independents produce about a third of the total output of crude oil and natural gas in the U.S. and drill approximately 90% of all exploratory wells in untested areas, seeking new reserves of oil and natural gas. These same independents operate most of the 450,000 "stripper" oil wells that produce an average of less than 3 barrels of oil per day but cumulatively contribute 1.2 million barrels daily to the U.S. crude oil supply (approximately 15% of domestic production). According to the American Association of Petroleum Geologists, independents make 80% of the significant U.S. oil and natural gas discoveries.

With most of the "easy" oil prospects having been exploited, today's independent is exploring in remote areas where risks and costs are high. Only one in five exploratory wells finds oil, and each well costs an average of $200,000. Low oil prices are causing the abandonment of thousands of "stripper" wells, which, once abandoned, are lost forever as a source of future oil. Unlike the major integrated petroleum companies that have extensive holdings and operations outside the U.S. to generate profits, the independent producers usually operate only in the U.S. and have only one revenue/profit center—the wellhead. Independents drill over 85% of all domestic oil and natural gas wells; without them our growing dependence on foreign sources of oil could be much larger. Continued deterioration of our domestic energy-producing capabilities by the deliberate supply and price manipulation of foreign governments is an untenable situation that puts our energy security in jeopardy.

III. SOLUTION APPROACH—*A role for the Federal Government*

Beginning in 1985, the Energy Research Advisory Board (ERAB), appointed by the Secretary of Energy, has repeatedly recommended that highest priority for energy research be given to federal support of oil R&D. In the six-volume strategic planning document *Guidelines for DOE Long Term Civilian Research and Development*, December 1985, the first of the ERAB recommendations was to "Reduce U.S. long-term dependence on foreign oil." Another ERAB report, *Geoscience Research for Energy Security*, issued in February 1987, concluded that "Oil and gas are given top priority because the major energy problem facing the nation in the intermediate future is a shortage of domestic liquid hydrocarbon fuels, which threatens the nation's energy security and international competitiveness." A third recent ERAB report, *R&D Initiatives for Energy Competitiveness* reinforces these conclusions: "Mindful of federal budget constraints, however, we have singled out as DOE priorities only those technologies that are both of critical importance in the next ten years and for which federal funding can properly play a major role. On this basis, ERAB recommends that DOE (first) support research initiatives to increase recoverable reserves and production of domestic oil and gas...."

In January 1988, Assistant Secretary for Fossil Energy, J. Allen Wampler, announced a new initiative in enhanced oil recovery (EOR): "Our target must be the estimated 300 billion barrels of oil in this nation that is either immobile or is mobile but currently unrecoverable." This initiative was announced, according to the January 18, 1988 "Inside Energy," after a nationwide survey of the private and state sectors conducted by the DOE revealed a consensus for an expanded federal role in oil recovery R&D "as long as it is done in partnership, not in competition, with the oil industry."

Although the U.S. has already produced over 125 billion barrels of oil, current estimates place an additional 300 billion barrels of oil in those reservoirs remaining in the ground after conventional recovery methods have been used. It is estimated that about 10%, or 30 billion barrels of this oil, could be recovered using EOR techniques already used and tested by the industry. Currently, approximately 500,000 barrels of oil per day are produced in the U.S. using some form of EOR technology. The remaining 270 billion barrels of in-place oil, however, remain a technological challenge to the industry.

New diagnostic technologies on the horizon will allow oil reservoir characterization investigations to be made with far greater resolution than is currently possible. Interwell seismic surveying methods with improved sources and receivers will allow tomographic images of a reservoir to be developed, in much the same way as the medical profession uses CAT scans. This information will also assist field developers in targeting the location of infill (interior) wells near known productive regions of a reservoir. If the number of unsuccessful wells can be reduced, the cost of produced oil will decrease. If injected fluids used in EOR treatments can be confined to regions of the reservoir that contain trapped oil, more reservoirs will become candidates for treatment.

Similar technology developments can also be envisioned for the way oil wells are completed in the producing formation to yield higher permeability flow paths for the oil to reach the well. Lower-cost well stimulation treatments for marginal producing wells and injection wells used in EOR treatments could also contribute to lowering oil prices.

The technology area of improved downhole logging tools is also a prime target for R&D efforts. Improved techniques have been developed for mapping fractures in producing reservoirs and for studying the fracture patterns in wellbores. New concepts in logging tools should be researched, based on needs already expressed by industry.

The U.S. has the most technologically advanced oil industry in the world, a basic research community that is second to none, a government highly supportive of science and technology, and a free-market industrial base. But more is needed. We must learn to transfer our applied research and development strengths to the problem of shortening the time from research to development to the marketplace. To really excel, we must try to better integrate our resources by exploring new partnerships among industry, the DOE laboratories, and universities, making optimum use of the capabilities of all. Closely focused R&D cooperation between industry, the DOE national laboratories, and universities with the support of the DOE will lead to technological advances.

These technological advances will create additional U.S. domestic reserves from the 300 billion barrels of remaining oil.

Based on our concerns for the nation's energy security and for the vitality of the domestic U.S. oil industry, together with our knowledge of how the DOE laboratories could help to alleviate part of the problem using technological means, Los Alamos National Laboratory and Sandia National Laboratories have established an Oil Recovery Technology Partnership. The transfer of existing technologies, developed under DOE-funded weapons and energy programs, will form a critical element of this new initiative. The expected result will be new technological options for the U.S. oil industry that achieve the objectives put forth by Assistant Secretary Allen Wampler.

IV. TECHNOLOGY TRANSFER AND U.S. INDUSTRIAL COMPETITIVENESS—

Forging a link between the U.S. oil industry and the DOE weapons laboratories

Technology transfer in a variety of forms has been occurring at the DOE laboratories almost since their inceptions, but it was not until 1980 that Congress enacted legislation that clearly declared technology transfer from the federal laboratories to be a national priority. The record of the DOE laboratories in transferring technology to industry includes many noteworthy successes. The DOE weapons laboratories have, from their formation, been dedicated to the full range of research and development activities associated with the development and delivery of a product. This philosophy of frontier science, sound engineering, and development of quality products has been applied to Laboratory programs.

Sandia has effectively transferred technology to industry in many defense and energy areas. A joint program with Atlas Powder Company to improve blasting technology is currently being conducted. Sandia, with the world's most sophisticated radiation-hardened microelectronics facilities and capabilities, is collaborating with the University of New Mexico on a Sematech-sponsored project to recover the U.S. competitive position in microelectronics.

Sandia is recognized for a number of significant technology transfers that have been incorporated by the oil industry. Perhaps most notable among these has been the polycrystalline diamond compact drill bit technology which is used world-wide. Other examples are downhole steam generators and high-efficiency insulated tubing strings for thermal enhanced oil recovery, the science that relates *in situ* stress conditions to natural and induced hydraulic fractures, anelastic strain recovery technology for measuring *in situ* stress, high-temperature electronics for logging tools, a range of drilling fluid developments, and numerous geophysical instrumentation systems.

Los Alamos and the International Business Machines Corp. (IBM), which have collaborated on many projects over four decades, are currently collaborating on development of a new supercomputer. The project will include research in computer design and parallel computing which uses many computer processors to simultaneously solve different parts of the same problem. As the world's largest user of existing supercomputers, Los Alamos will define the programmer and user requirements of the supercomputer, then test IBM's prototype. Los Alamos is also currently conducting research with several computer equipment manufacturers. Los Alamos has also worked extensively with Cray Research on the development of the Cray supercomputers that currently form the backbone of the Los Alamos Computing Center. The interactions between Los Alamos and Cray Research and IBM in the past and with Cray, IBM, and Digital Equipment Corp. today have helped keep U.S. supercomputer companies ahead of international competition.

As stated by the director of the Los Alamos National Laboratory, Siegfried Hecker, the Laboratory has increased its interactions and work for the private sector and Hecker expects this to accelerate in the future. "Los Alamos and the other federal laboratories have been strongly encouraged by Congress to transfer the technologies developed with federal support to the private sector."

Director Hecker went on to say, "Technology push from a laboratory is seldom successful unless there is a strong market pull guiding applied research and development. That is why Los Alamos has promoted a new approach with the private sector—one of creating partnerships or joint ventures to develop relevant technologies. I believe that this is the area where the federal laboratories, particularly the DOE laboratories, can contribute significantly to U.S. economic competitiveness. It represents pre-commercial, pre-competitive applied research and development that will provide the technology base for many U.S. corporations to develop products and compete against countries like Japan."

Recent efforts by New Mexico Senators Pete Domenici and Jeff Bingaman have been directed at increasing the involvement of the DOE laboratories in oil and gas research. At the request of Senator Domenici, Sandia hosted a meeting to evaluate technology exchange between the DOE laboratories and the oil and gas industry. Technical exhibits were prepared for this meeting by Los Alamos, Sandia, and Lawrence Livermore that illustrated some of the emerging technologies that could contribute to enhanced domestic production of oil and gas. Attendees at the meeting were principally senior representatives from the major oil companies and independent producers from the region.

Senator Domenici said he is convinced the national laboratories already have scientific talent, expertise and equipment that can be translated to improved technology for finding and producing hard-to-recover oil. But the capabilities are going unused by the private sector for several reasons, including a tradition that does not allow the use of public institutions for private gain.

"These are not easy concepts to get around, but... we just flat don't have the luxury of having a lot of science and technology languishing," Domenici said.

V. THE OIL RECOVERY TECHNOLOGY PARTNERSHIP—*A new DOE initiative*

The DOE has supported a new initiative to put the domestic oil industry (majors, independents and service companies) in a position to use the scientific and engineering resources of the DOE laboratories, especially the DOE weapons laboratories, to acquire new technologies for improved domestic oil recovery. Emphasis in this initiative will be directed at transferring existing technology, largely derived from federally funded weapons and energy research, directly into the hands of the oil industry.

Bringing the talents of the DOE laboratories to bear on this significant national problem in a collaborative industry-guided program is consistent with the mission statements of the DOE weapons laboratories. The importance of this activity was further clarified in a statement made by President Ronald Reagan in February 1988—"One focus of the quest for excellence plan would be to free federal laboratories, including defense labs, to aid in making American products and technology better and more competitive."

The national laboratories, charged with the mission of providing the scientific base and nuclear weapons necessary to ensure the security of the nation, are continually involved in "cutting-edge" research in engineering technology and the physical sciences. These research efforts, funded primarily through the DOE, lead to technology developments that could have almost immediate applications to other national problems, including improving the domestic production of oil.

With the support of DOE, Los Alamos National Laboratory and Sandia National Laboratories have initiated an Oil Recovery Technology Partnership that could help make the U.S. oil industry more competitive and less dependent on imports and also make better use of federal investments in science and technology. This partnership is based on the results of two years of discussions and information exchange between scientists and engineers at Los Alamos and Sandia and those from numerous domestic oil industry companies. These discussions indicated that the domestic industry is at best only vaguely aware of the technological resources that can be placed at their disposal through the DOE laboratories.

Industry is interested in ways to benefit from DOE laboratory expertise, equipment, and facilities and to have access to defense spin-off technologies that could have near-term applications in improved oil recovery processes. The DOE laboratories understand that to achieve success in moving research results efficiently into the private sector, the oil industry must become an active partner with them, especially in providing an upfront understanding of industry needs and of the technology-oriented research and development that must precede utilization and commercialization.

Los Alamos and Sandia have actively gathered information from the oil industry, have participated in collaborative field and laboratory experiments with them, have experience and specialized capabilities in many technical areas derived from federally funded pioneering weapons research that could have near-term relevance to oil production, have an infrastructure to support technology transfer, have a tradition and track record of R&D productivity, and have the commitment of top management to strengthen the competitiveness of the U.S. energy industry. It is from this vantage point that the Oil Recovery Technology Partnership was formed. This initiative proposes the following features:

1. An organizational structure and project management mechanism that includes U.S. industry (majors, independents, and service companies) up front to guide, evaluate and prioritize the collaborative R&D efforts, with special attention given to the needs of independents.

2. A commitment by the laboratories to emphasize the near term spin-off of defense and energy-related technologies to significant problem areas currently hindering the improved production of oil from mature fields.

3. A commitment by the laboratories to coordinate closely with industry to assure that industry needs guide the development of enabling technologies and incorporate industry expertise in applications, processing, and manufacturing.

4. An industry-guided project review mechanism.

5. A management structure for the partnership that will operate through the existing DOE Fossil Energy framework under the programmatic guidance and control of the DOE Bartlesville Project Office and the policy and administrative guidance and control of the DOE Albuquerque Operations Office.

Industrial interactions with the laboratories confirm that government funding is the key to demonstrate DOE commitment, to firmly engage the capabilities of the DOE laboratories, and to assure a strong start. Federal funding will also provide stability and will assure that results of generic and applied research are in the public domain. Funds provided by DOE will only be used to support the direct involvement of the national laboratories to apply their expertise to specific oil industry problems. Initial support from industry will be primarily in-kind contributions consisting of technical personnel, access to production and injection wells, field support, and access to accumulated oil field data. In the longer term, the partnership will seek industry funding in a variety of forms, including cost reimbursement, funds in agreements, and royalty or equity positions in exchange for intellectual property.

VI. INITIAL THRUST OF THE PARTNERSHIP—*Where do we begin?*

Activities under the partnership have been formalized with the receipt of $1.0 million from the DOE Office of Fossil Energy. During the first year of its operation, the partnership will be chaired by Los Alamos and co-chaired by Sandia. Technical emphasis will be directed initially at crosswell seismic investigations that can improve the characterization of known oil reservoirs by defining major structural features, and at providing assistance to independent oil producers who have been particularly hard-hit by the recent low oil prices.

The DOE laboratories have studied phenomena that overlap strongly with technical concerns of the domestic energy industry. Examples that have been given the highest priority by the oil industry include the influence of reservoir rock heterogeneities on the propagation of seismic waves; use of crosswell seismic surveying techniques to identify oil reservoir heterogeneities; and the propagation and mapping of natural and man-made fractures in an oil reservoir.

Consistent with industry guidance, the partnership has identified crosswell seismics as a strategic technology area in which collaboration between the laboratories and industry will advance this technology. To better identify needs and provide partnership direction, an industry forum for this technology is being established. The objective of the joint national laboratory/industry forum on crosswell seismology is to enhance the use of crosswell techniques as a diagnostic tool for high-resolution reservoir characterization and process delineation. The joint industry forum will further this objective by providing a mechanism for

(1) Presentation and review of crosswell seismic proposals seeking DOE support.

(2) Establishing priorities through review and comment by the forum members on specific proposals.

(3) Evaluating which national laboratory capabilities and areas of expertise are likely to have the greatest impact on developing and/or applying crosswell seismic technology.

(4) Leveraging industry dollars with federal funds by defining specific collaborative industry/national laboratory projects.

(5) Facilitating the industrial implementation of laboratory and field results related to crosswell seismology.

The first meeting of this industry forum will take place in March 1989. Proposals that will be reviewed by this forum are currently being prepared.

Efforts are currently in progress to develop a collaborative project between Los Alamos and an independent oil producer to improve the efficiency of water flooding operations in one of the independent's fields. Conductive fractures in this formation are channeling water floods, resulting in very high water/oil ratios and unswept portions of the reservoir. Downhole fracture mapping techniques will be employed to locate major fractures, and this information will guide the location of water injection wells for more effective sweeping of the reservoir oil.

Sandia has developed a collaborative project with another independent oil producer to improve the oil recovery from low permeability, possibly naturally fractured reservoirs, which historically have had very limited production from a significant resource. Investigations will be conducted to determine if natural fractures exist and to define their effect on production. The overall objective will be to use this information in the design and execution of well stimulation and well completion practices that will lead to improved production.

Both of these partnership projects are expected to result in field activities commencing during the second quarter of CY 1989. These projects typify the production problems being encountered by independent oil producers that can be effectively addressed by advanced technologies developed by DOE laboratories.

VII. PARTNERSHIP ACTIVITIES IN THE FUTURE—*Where are we going?*

Emphasis during the first phase of the partnership (FY 1989–90) will be on immediate and short-term results that will have rapid technological payoffs for major and independent oil producers. This phase will involve a partnership between industry and Los Alamos and Sandia National Laboratories. Projected partnership activities for FY 1990 require a budget of $5.0 million.

This funding level will allow Los Alamos and Sandia to participate in numerous full-scale reservoir characterization investigations with both major and independent oil producers. Reservoir heterogeneities could be examined in a variety of reservoir formations that are typical of the domestic oil fields currently in production. In parallel with these field investigations, improvements in current geodiagnostic technologies could also be expected. At this level of support, the oil industry will get a firm message that DOE (through its national laboratories) is committed to providing technological assistance for enhanced recovery of domestic oil.

During the second phase of the partnership (FY 1991–93) significant emphasis will continue to be on short-term results for technological payoffs in reservoir characterization and enhanced recovery but other areas of research and development will be added, including environmental concerns and advanced concepts. During phase two, other DOE laboratories and academic institutions may be added to the partnership team to further expand its technical expertise. Industry participation will continue to be stressed and collaborative projects with industry will be the normal operating mode of the partnership.

If collaborations are successful during this phase, we would expect an increasingly larger contribution to the collaborative support to come from industry funding. Support from industry would provide a measure of the importance with which industry viewed this program. In addition to support for collaborative projects, enhanced funding from industry could also be applied to full-cost-recovery funds-in agreements covering work that could be proprietary to the supporting industry. As the partnership matures during this phase, the initiation of longer term development technologies is also envisioned. Implementation of these new technologies could become the focus and mission of the partnership beyond FY 1993.

The partnership project office will have a steering committee composed of representatives from the oil industry, DOE, and the national laboratories. This committee will review partnership accomplishments and future goals and ensure that proposed and ongoing projects continue to address the highest priority concerns of the industry for enhancing domestic oil production and providing a secure source of liquid fuels for the nation.

TESTIMONY TO THE
SUBCOMMITTEE ON ENERGY, RESEARCH & DEVELOPMENT
OF THE
HOUSE COMMITTEE ON SCIENCE, SPACE & TECHNOLOGY

February 22, 1989

"CONTINUOUS FIBER CERAMIC COMPOSITE INITIATIVE"

Mr. Chairman, we appreciate this opportunity to present written testimony in support of the development of a new class of structural materials, ceramic composites. We specifically request that an additional appropriation of $4 million be provided to the Office of Industrial Programs within the Department of Energy in the FY90 budget as the first step in a sustained commitment to establish a U.S. technology base in ceramic composites.

The United States has forfeit a preemptive position in manufacturing traditional ceramics to the Japanese. Japan has recently announced an $80 million eight-year effort to develop fiber reinforced ceramic composites. Unless the United States acts decisively, the technical lead we now enjoy in ceramic composites will be dissipated.

Over the past two months, representatives of United States industrial firms have met to discuss the need for a large congressionally supported effort to fully develop fiber reinforced ceramic composites. These meetings, involving many of the companies currently involved in the development of ceramic composites, have focused on the need for a multi-year program involving industry, universities, and national laboratories working in concert to bring ceramic composites to maturity. An outline of a program is evolving which would assure United States competitiveness in high temperature structural materials. These companies intend to continue their support for a comprehensive congressionally funded program on the development of ceramic composites.

CERAMIC COMPOSITES

Ceramics are non-metallic systems that are thermally and chemically stable at temperatures exceeding 3000F, whereas metals and alloys are limited to service temperatures below 1800F. However, ceramics fail in a brittle fashion, which limits their structural usage, while metals exhibit ductility and toughness distinguishing them as excellent structural materials. Composites are a general class of materials that can be defined as the sophisticated combination of two or more distinguishable materials. Composites have more desirable properties than their individual constituents. Thus, a ceramic composite, where the ceramic material is modified by the addition of fibers that add toughness will resist high temperatures and harsh environments, but will not suffer from the brittleness that makes monolithic ceramics poor structural materials. These materials are, however, in their infancy. A comprehensive, well organized effort is required to bring these materials to maturity.

WHY CERAMIC COMPOSITES ARE IMPORTANT TO U.S. ENERGY EFFICIENCY

The efficiency of engines and electric power generating plants improves as the operating temperature is increased. Higher efficiency means less fuel consumption and cheaper energy. For example, increased efficiencies of 10-30% are possible in power generation facilities through the use of ceramic composite air heaters. Other applications with similar benefits include industrial turbines, chemical processing, and steel processing. Such advanced systems, because of higher operating temperatures which exceed the limits of metals, demand advanced materials like fiber reinforced ceramic composites. Total energy savings for these industries could exceed 0.5 quads/yr.

An additional benefit from the use of ceramic composites is reduced dependence on strategic elements. Metal alloys require strategic elements like chromium and cobalt that come mainly from unstable foreign sources. Ceramic composites utilize elements like silicon, aluminum, and carbon, which are readily available. Clearly, ceramic composites are an enabling technology that can free U.S. industry from foreign dependence.

The U.S. is not alone in recognizing the importance of this technology. The Japanese have launched a concerted effort to develop ceramic composites, to complement their superiority in monolithic ceramics. Today the U.S. is ahead. However, if we do not aggressively pursue this technology and they do, the results will be very severe for U.S. industry. Since composites are generally tailored to a specific application (that is they go from raw material to processed shape in a continuous step), they will not be available as commodity materials in the world market as are steel ingots. Without the development of ceramic composite processing capability, high efficiency industrial systems will not develop.

The recommended program is a $100-million dollar effort involving multiple firms. This program will include process development with support from disciplines in fracture mechanics, non-destructive testing and interfacial micro-analysis. The process development would address major issues such as ceramic fiber development, fiber-matrix interface control, and matrix deposition. The combination of industry, national laboratories, and universities will provide a solid base to promote industrial usage.

SUMMARY

To summarize, B&W believes that ceramic composites will be the next major advance in structural materials. At maturity this will enable the design and construction of advanced engines, power generation equipment, and chemical processes operating at temperatures beyond the reach of today's materials. The higher operating temperatures of these advance systems will in turn mean higher efficiencies for these industries and give them a real advantage in world competition.

The development of ceramic composites is a major technical challenge. This challenge requires and deserves the unified, concerted efforts of U.S. industry, national laboratories, and universities. Furthermore, the Federal Government should co-fund this effort and serve as its integrator. We believe that the proposed program can succeed and we request your support for this program.

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